Control Engineering

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

A McGRAW-HILL PUBLICATION

PRICE 50 CENTS

AUGUST 1956

Determining a Pneumatic Controller's Characteristics

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Flight Test Developing Autopilots

How Your Patent in Control is Processed

Control Systems within the Computer

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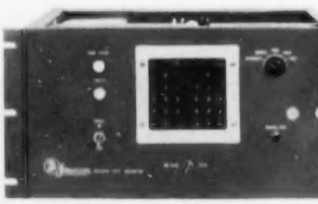
Greater input flexibility | For desk or rack mounting



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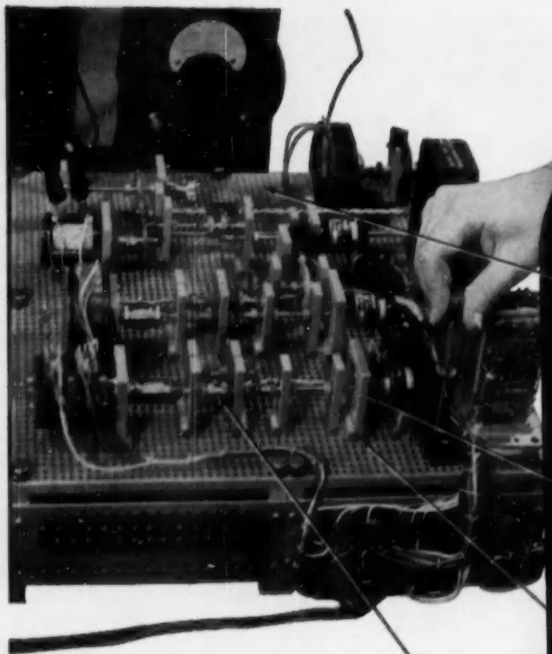

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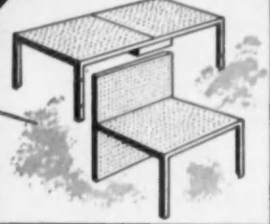
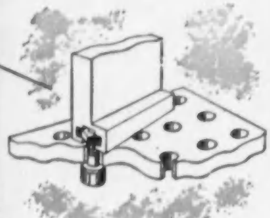


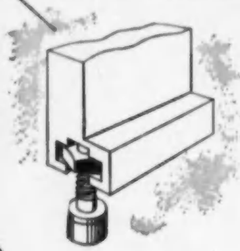
1

Foundation Boards, with drilled holes, can be combined in vertical and horizontal planes and because the boards are cut from rolled stock, stress-relieved and ground flat, they will not warp.



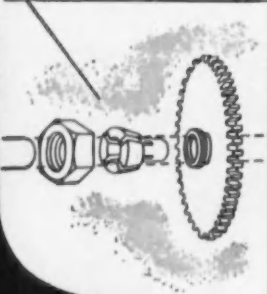
2

Mounting Blocks can be rotated and moved in any part of 360°. Captive nuts are free to travel the length of the base slot. This permits the blocks to be adjusted in a lateral direction.



3

No worn thread trouble. Steel captive nuts in mounting blocks are inherently reliable, and can be replaced if damaged.



4

Gears are attached to shafts with tapered collets which fit securely into integral tapered hubs. Guaranteed true balance and concentricity.

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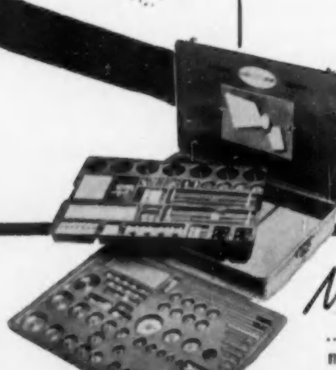
The immediate delivery of these versatile precision-built components, plus the exclusive advantages listed, combine to make this equipment extremely economical, practical and easy to use.



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FEATURE ARTICLES

IDEAS AT WORK

DEPARTMENTS

PRINT ORDER THIS ISSUE 31,790

Published monthly by the McGraw-Hill Publishing Co., Inc., Executive, Editorial, Advertising and Subscription Offices: McGraw-Hill Building, 330 West 42nd Street, N. Y. 36, N. Y. Publication Office, 99-129 North Broadway, Albany 1, N. Y.; entered as second class matter at the Post Office at Albany, N. Y. Donald C. McGraw, president; Paul Montgomery, executive vice-president; Joseph A. Gerardi, executive vice-president and treasurer; John J. Cooke, secretary; Nelson Bond, executive vice-president, Publication Division. Ralph B. Smith, vice-president and editorial director; J. E. Blackburn, Jr., vice-president and circulation director; Joseph H. Allen, vice-president and director of Advertising Sales; FOR SUBSCRIPTIONS, write to: Control Engineering-Subscription Service, 330 West 42nd Street, New York 36, N. Y. Orders must indicate company and position. Allow one month for change of address. Single copies 50¢. United States and possessions: \$3 for one year, \$4 for two years, \$5 for three years. Canada: \$4 for one year, \$6 for two years, \$8 for three years. Latin America: \$10 for one year, \$16 for two years, \$20 for three years. Other countries: \$15 for one year, \$25 for two years, \$30 for three years. Printed in U.S.A.

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SHOPTALK

EDITORS PACE BUSY FIELD

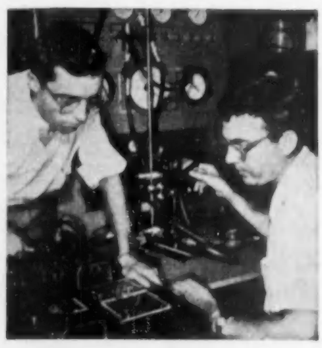
Pacing the inordinate activity in the field (page 21), two CtE editors recently took off for far-away places and two others signed on at home. Ray Auger traipsed off to Europe to sail back a small boat. Gene Grabbe left for Paris where he addressed the International Congress of Automation on June 20. Frank McPartland came in—fresh from engineering jobs at Diesel Economy Devices and American Machine & Foundry—to handle our *New Products* section and birddog future news stories in the field. And, finally, who should turn up on June 11 but Jolly Roger Wollstadt, our "editorial factotum" of last summer (see *Shoptalk*, October '55). Roger will help Warren Kayes, our back-of-the-book Chief, in his arduous job of verbally styling each issue.

NEWS THAT'S FIT TO PRINT

The New York Times, which prints "All the News That's Fit to Print", found our July feature news story and *Industry's Pulse* fittin' for a column in the Business section of its June 18 edition. We are, of course, delighted and flattered.

YOU ASKED FOR IT—HERE 'TIS

Dynamic characteristics of available industrial control products are like the vital statistics of Marilyn Monroe in that they are much sought after, but are unlike Marilyn's statistics in that once you have the characteristics, you can do something with them. Below, and on our cover this month, you see du Pont's Bob Bigliano (left) and aide Ed Scofield running off dynamic tests on a stacked controller. A similar picture of the two appeared in our report on du Pont's control engineering (CtE, Sept. '55, p. 65). The fact that this company had a well-defined and fundamental method for determining the wanted characteristics whetted reader appetites. "Why not," one wrote, "run a complete story on how to do it?" Here 'tis (see page 72), after months of planning and working with author Bigliano. And in the fall we plan to publish actual test data involving commercially available products.



FEEDBACK

To the Editor—

I have noted your articles on Spring Powered Position Servo in the January and March '56 issues of Control Engineering.

We have interests in these areas and would like to know of any commercial or military requirements extant.

I could not determine from your article whether the devices you designed were for an actual use or were the result of some mental gymnastics.

Richard G. Schimpf
Elgin, Illinois

The servo was, commercially, a stab in the dark. The basic idea (spring power for light weight and fast response) seemed good, and the article was accepted on the basis of design interest. A model of the torque amplifier (described in the January '56 issue) was built; it worked. In its original version it had a specific purpose: to power the counter of a sensitive altimeter. The Air Force has been trying to get a counter altimeter for some time.

It shouldn't be too difficult to calculate exact performance figures for the spring device and thus to determine in what areas it is superior to other types of self-contained position servos. Without a specific type of size to work on, however, it's impossible to give exact figures. Such factors as maximum angular motion required between windings, velocity and torque

THE PROBLEM FORUM

This month we repeat the problem posed in June and publish one answer, plus our commentary. Next month we will publish another solution selected from the many submitted.

Problem . . .

Needed: a 5,000-point temperature-alarm system that monitors in 50 groups of 100 each. All within any group have the same pre-set temperature of between 85 and 105 deg C. The specified accuracy is within plus or minus 2 deg C. Required: only low-temperature alarm; automatic shutdown is unnecessary. Once per hour per position scanning is satisfactory.

Application: monitor surface temperature of 5,000 brass concentric-tube heat exchangers 24 in. long and 1 in. in diam. Distance between control panel and measuring points: max. 500 ft; average, 50 ft. As the measuring area is often contaminated with explosive vapors, the energy limit of ac circuits is 200 ergs per cycle.

Adjustment of alarm temperature for each group of 100 points from a central location is a desirable feature, but to minimize cost, manual setting of each point is acceptable.

The savings will be from: 1) reduced labor costs, as operators now make all readings with portable pyrometers; 2) isolation of faulty product before it leaves the department for subsequent manufacturing.

Allowable total installed cost: $10 to $15 per point; $30 per point definitely prohibitive—and **just that** is the problem.

. . . and one solution

To the Editor—

I am convinced that there must be more to this problem than meets my eye. On the basis of my interpretation of the information given, I believe that the plant engineer should be able to do this job for $50,000 plus labor and engineering, maybe even less.

My parts list would be approximately as follows:

- Cross-bar switches—North Electric
- Thermistors—General Electric
- Relays—Barber-Colman
- Diodes, germanium—
- Misc. precision resistors
- Batteries—Saft
- Clips—Mueller (alligator)
- Controls for switching—North Electric parts and my special design
- Zenner diodes—National Fabricating

The thermistors would be mounted in a protected manner in the clips, which would be clipped to the point to be monitored. The clip-to-brass-tube would be the ground and soon the thermistor and clip would be at the temperature of the tube. It would probably be necessary to place a sleeve over the clip to reduce heat loss.

The cross-bar switch would select the wires to the thermistors nine at a time and its 10th point would be

requirements, weight and size, must be established before a competitive evaluation can be calculated. Ed.

Suggested: a new industry breakdown

The editorial in our July '56 issue explained the difficulty in getting from the Spring 1956 Census of Manufactures a realistic picture of the commercial life of our fields in 1954. We pointed out that Nathan Golden's division in the Dept. of Commerce is aware of the difficulty. His deputy, Cortlandt Van Rensselaer, furnished (WOC) by the Scientific Apparatus Makers Association, has suggested a new breakdown. Van Rensselaer evolved his new classification while trying to arrive at a functional classification of general-purpose electronic test instruments. Here is his functional classification for scientific, industrial, and technical instruments and equipment. Look it over. See if it

(*Continued on page 8*)

PROBLEM FORUM

used for selecting the reference. If any one of the nine points selected was materially different than the reference, the Barber-Colman relay would be energized (this takes as little as 100 microwatts—maybe less) to signal the deviation.

Saft batteries would be used because they are hermetically sealed. The Zenner diodes would be used to provide added protection against a high voltage appearing on a signal line and causing a spark. If the brass tube is not a satisfactory ground, then a two-wire system could be used with only the added cost of more wire.

John M. Graham
Bellwood, Ill.

Our Comments:

1. The problem says installed cost up to $75,000. Graham allows only $25,000 for engineering and installation. Realistic?

2. It will be necessary to preselect thermistors, hence premium price. Or they will have to be adjusted at installation, with another increase in cost.

3. Graham's plan does not provide for automatic location of the particular exchanger in the 5,000 that is off-temperature. But this is not a serious objection, since his method does narrow the search to a group of ten. From that point, it would not be too difficult to single out the particular exchanger. Ed.

fits the instruments you use. Constructive criticism will convince the Dept. of Commerce that there is a need and will help in the development of proper classifications. Ed.

100. Instruments Used Primarily for Test and Measurement
110. Electrical Quantity and Characteristic Measuring and Testing Instruments
120. Electronic Property Testing and Measuring Instruments
130. Mechanical Force, Motion and Rotation Measuring Instruments
140. Nuclear Radiation Measuring and Testing Instruments
150. Physical Property Measuring, Testing, and Inspecting Instruments
160. Chemical Property Measuring and Testing Instruments
190. Instruments Used Primarily for Test and Measurement, Not Elsewhere Classified

200. Instruments and Equipment Used Primarily for Process Recording and Controlling
210. Electrical Quantity Recording and Controlling Instruments
220. Temperature, Humidity, and Moisture Recording and Controlling Instruments
230. Pressure Recording and Controlling Instruments
240. Flow and Liquid Level Recording and Controlling Instruments
250. Gas Analysis and Chemical Property Recording and Controlling Instruments
260. Mechanical Motion, Dimension, and Rotation Recording and Controlling Instruments
270. Timing, Cycle, and Count Recording and Controlling Instruments
280. Automatic Controlling or Regulating Valves
290. Instruments and Equipment Used Primarily for Process Recording and Controlling, Not Elsewhere Classified.

300. Optical Instruments and Equipment (other than Ophthalmic Goods)

400. Research Laboratory Apparatus and Equipment

Internal feedback at work again

To THE EDITOR—

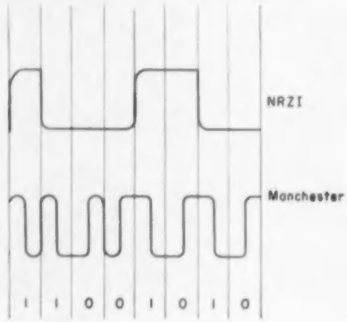
Fowler's article, "The Computer's Memory, Basic Digital Series No. 8", in the May issue of CONTROL ENGINEERING gives the author's views on this subject. Since storage is a very important part of a computer system, I feel compelled to comment on cer-

FEEDBACK

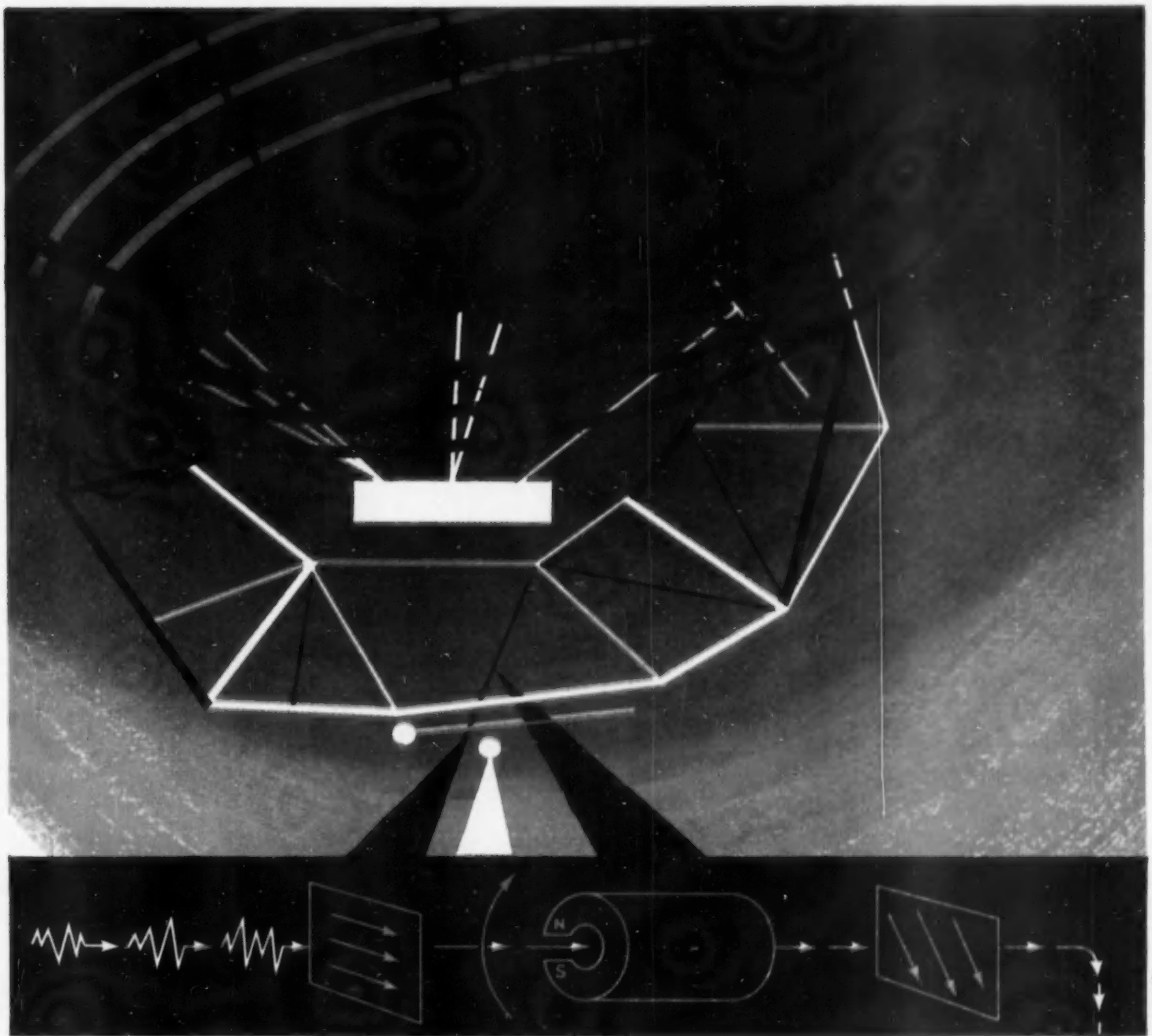
tain inaccuracies and omissions of this article.

1. The term "storage" is preferred to "memory." (IRE and ACM terminologies)
2. The NRZ system is the most commonly used today, not the RZ. The author's statement would have been true several years ago.
3. In addition to the RZ and NRZ recording systems, there are the NRZI and Manchester systems. The NRZI is similar to NRZ except that the signal is inverted whenever a 1 appears. This has the advantage that if a code is used on tape or parallel drum in which at least one 1 appears in every row, no separate timing channel is required.

In the Manchester system 0's and 1's are recorded as full cycle square waves of opposite phase. In this system the output signal contains no dc components. The packing density is less than for NRZ. The following diagram shows the NRZI and Manchester systems.



4. The author speaks of short access time and long access time storage systems. In the typical computer today the storage hierarchy consists of fast (microseconds—e.g., magnetic-core storage), medium (milliseconds—e.g., drum storage) and slow (seconds—e.g., tape storage). This hierarchy is essential for the solution of complex business and scientific problems of today.
5. The original Williams tube was a serial storage device which operated on a different principle from the parallel electrostatic storage systems in use today. The term "Williams tube" has come to be applied to all electrostatic storage systems.
6. To round out the picture of storage devices, superconductive and barium titanate capacitative elements should have been mentioned.
7. Considering the importance of magntic tape, the author devotes but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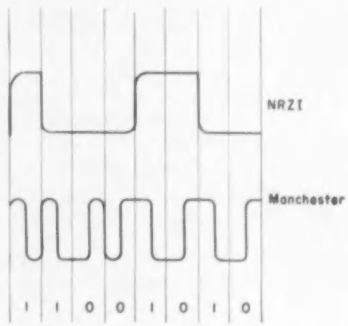

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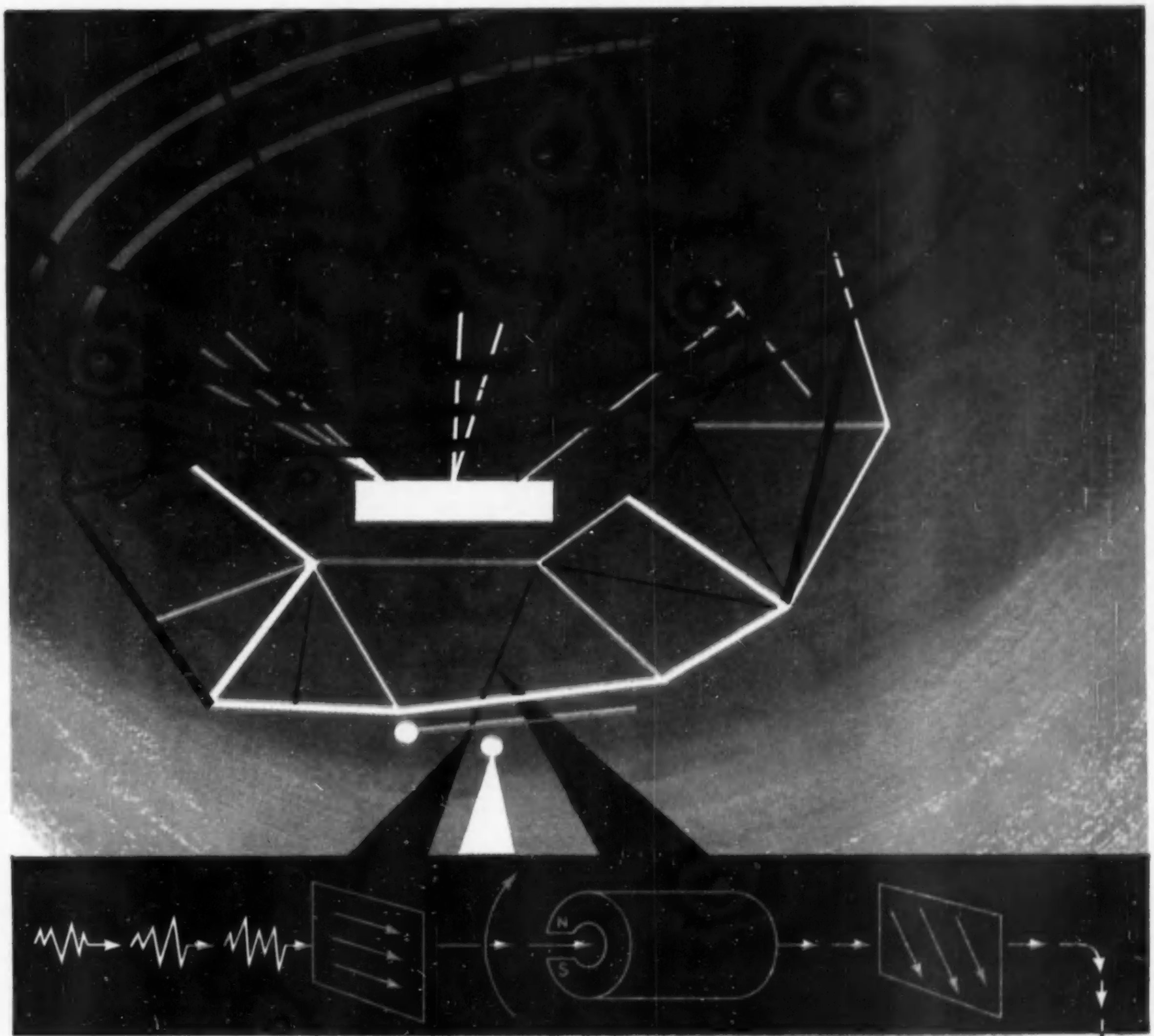

a short paragraph to this storage medium and speaks only of metal tape. With the advent of thin Mylar tape it is practically certain that all computers of the future will use this type of magnetic tape. New tape units read in the order of 15,000 characters per second.

8. In this reader's opinion there is little merit in introducing new terminology such as "cyclic" and "progressive" recording systems since they add little to the understanding of the storage device. For example, regeneration is discussed for cyclic storage only. Regeneration is also a necessary part of electrostatic tube storage classified as a parallel system. The original serial Williams tube fits nowhere in the author's chart.

E. M. Grabbe
La Canada, Calif.

Is this another case of West versus East? We think not. Gene Grabbe has provided technical commentary on an article—commentary that adds to the article's value. Ed.

To the Editor—

I thank you very much for your effort in publishing an article on rate transformers, (page 96, June '56 issue of Control Engineering).

This article is the only one available on this subject in technical literature and I am sure that control engineers will find valuable material therein. To make this subject-coverage more complete I suggest that you publish an article on that same subject, but dealing only with its theoretical aspect.

Michel Mamon
Woodside, N. Y.

We cannot take our bows without acknowledging Mr. Mamon's suggestion (see Problem Forum, May '55 issue of Control Engineering) that we publish an article on rate (or stabilizing) transformers. He described the problem and gave us a list of possible authors. One of those listed, H. B. James of Westinghouse, was able to furnish an article (CtE, June '56, p. 96) that shows the best present-day practice in designing rate transformers into control systems, including systems that use magnetic amplifiers.

Mr. Mamon asked; we searched for an author and delivered. Tell us what else you'd like us to publish. Mayhap the article you want reposes in the editorial quiver awaiting its turn, or the extra prod of an interested reader to push it into print. Ed.

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CHARACTERISTIC	CONDITION	VALUE
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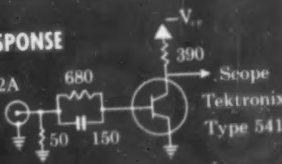
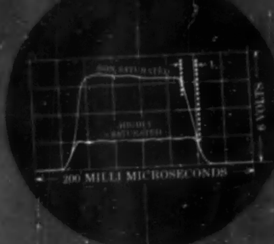
"OFF"	$V_{be} = -0.10$V., $V_{ce} = -4.5$V.	$I_c = -150\ \mu a$ MAX.
h_{fe} (COMMON EMITTER CURRENT GAIN)	$V_c = -3$V., $I_e = -.5$ ma.	16 MIN.
C_{ob} (COMMON BASE OUTPUT CAPACITY)	$V_c = -3$V, $I_e = -.5$ ma.	6 $\mu\mu f$ MAX.
I_{co} (COLLECTOR CUTOFF CURRENT)	$V_{cb} = -5$ V	3 μa MAX
I_{eo} (EMITTER CUTOFF CURRENT)	$V_{eb} = -5$ V	3 μa MAX.

MAXIMUM RATINGS

$V_{ce} = -6$ V $I_c = -15$ ma. $P_c = 10$ mw @ 40°C.

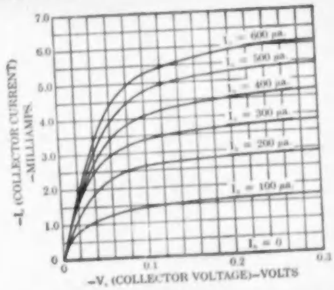
PULSE RESPONSE



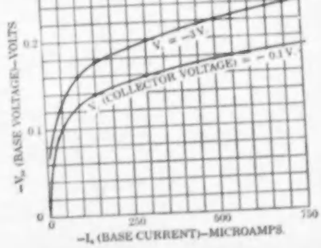


Test Conditions: V_{cc} is set to -6V and pulse input is adjusted until transistor is just in saturation. V_{cc} is then lowered to -1.5V for saturated pulse curve. t_s = hole storage time.

COLLECTOR CHARACTERISTIC IN SATURATION REGION



INPUT CHARACTERISTIC



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LANSDALE, PENNSYLVANIA

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Woodside, N. Y.

We cannot take our bows without acknowledging Mr. Mamon's suggestion (see Problem Forum, May '55 issue of Control Engineering) that we publish an article on rate (or stabilizing) transformers. He described the problem and gave us a list of possible authors. One of those listed, H. B. James of Westinghouse, was able to furnish an article (CtE, June '56, p. 96) that shows the best present-day practice in designing rate transformers into control systems, including systems that use magnetic amplifiers.

Mr. Mamon asked; we searched for an author and delivered. Tell us what else you'd like us to publish. Mayhap the article you want reposes in the editorial quiver awaiting its turn, or the extra prod of an interested reader to push it into print. Ed.

FEEDBACK

Fatter engineering paychecks?

To the Editor—

As an engineer, I have both a selfish and an altruistic interest in Mr. McGraw's new editorial series on the manpower shortage. It will be interesting to observe how (or *if*) he will deal with Jay Forrester's hot potato. (To be explicit, Control Engineering reports Mr. Forrester as saying, in effect, that if there were *really* a shortage of engineers, it would be reflected in their salaries. We know, in fact, that there is a shortage, and Mr. Forrester's remark is apparently an irony directed at the obviously rigged market. Any job-hunter is aware that all that glitters in *The New York Times'* want ads is not gold.)

In any event, there is a herculean educational task before you. The educational system is soft to the core. Anti-intellectualism is stronger than at any time in the century. Nobody *wants* their child to be an engineer, or a scientist, or a mathematician. The public is a pragmatic body. When they see that engineers and teachers have the salaries, responsibilities, and prestige now afforded notion salesmen, bricklayers, and junior executives, then will they educate their children to enter the hard field of science. No amount of war-scare and elaborate presentation is going to cover up the fact that there is no money in engineering. And by a well-known and long-tested formula
(No Money) = (No Importance).
So it looks as if Mr. McGraw's message should be directed at our industrial managers.

A. Lange
Wayland, Mass.

Mr. Lange argues that the engineer's happiness and well-being depend on his income. Certainly it is worthwhile to direct management's attention to the current series of McGraw-Hill editorials on engineering manpower. We suggest that each interested reader of this magazine mark the series of editorials for his management's attention. Originating in Dexter Keezer's Economics Dept., the McGraw-Hill editorials are founded on detailed study. They include suggestions for improving the "production" of engineers and for their maintenance as happy individuals. Keep reading them; they contain real food for thought—and action. Ed.

NOW...A GREAT, NEW ADVANCE IN MEASUREMENT AND CONTROL OF RELATIVE HUMIDITY

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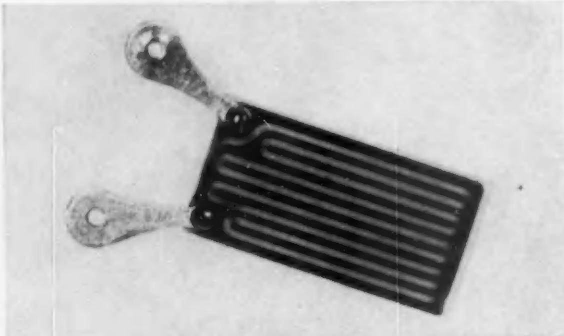
EL-TRONICS

HUMIDITY SENSING ELEMENT

An entirely new principle . . . completely stable over long periods . . . mass produced at low cost.



Composed of a specially treated plastic material, the El-Tronics Humidity Sensing Element (patented) is only ⅝″ wide, 1½″ long, and 1/32″ thick.

The resistance of the element varies as the logarithm of the relative humidity. The signal produced by the resistance change may be amplified and used to operate indicators, recorders, and controls.

RAPID RESPONSE

Reaction to humidity change is rapid, 67% of the change registers within 30 seconds on standard production elements. This reaction time can be reduced to 1 second for special applications.

ACCURATE OVER WIDE TEMPERATURE RANGE

For use over a wider range than heretofore possible, from -5° to 80° C (23° to 176° F), the standard element has a repeat accuracy within 3% R.H. Long-term stability and maintenance of calibration under adverse conditions are additional features of the El-Tronics Humidity Sensing Element.

MANY APPLICATIONS

The El-Tronics Humidity Sensing Element is applicable to the entire field where relative humidity is measured or controlled. This includes humidifiers, dehumidifiers, dehydrators, dryers, home and industrial air conditioning, packaging process control, industrial, educational, and government laboratories.

PROVED PERFORMANCE

The El-Tronics Humidity Sensing Element is the result of five years of research and intensive tests under a wide range of operating conditions.

SPECIFICATIONS

Standard Ranges, R.H.: 10-100%, 20-100%, 40-100%
10-50%, 20-50%, 10-25%
Ambient Temperature Range: +23° to 176° F
Repeat Accuracy: Within 3%
Reaction time, standard models: 67% of change registers within 30 seconds
special models: 67% of change registers within 1 second
Dimensions: ⅝″ wide, 1½″ long, 1/32″ deep

FOR COMPLETE INFORMATION ON QUOTATIONS . . . PHONE . . . WIRE . . . OR WRITE:

EL-TRONICS INSTRUMENTS FOR THE MEASUREMENT AND CONTROL OF RELATIVE HUMIDITY

EL-TRONICS *Laboratory* HYGROMETER

Complete range of 10 to 100% R.H. Measures to 1% R.H.

MODEL 101

This is a precision 3-scale measuring instrument and can be used as a secondary standard. It is accurate within ±1% R.H. This hygrometer is plugged into a 110 volt a-c outlet to operate and is compensated for line voltage variations.

SPECIFICATIONS

Ranges: 40-100% (2% Graduations)
20-50% (1% Graduations)
10-25% (1% Graduations)
Calibration Accuracy: 1% R.H.
Power: 105-125 volts, 50-60 cycles
Size: 8″ x 10½″ x 10½″
Finish: Hammertone Gray

EL-TRONICS *Portable* HYGROMETER

Lightweight . . . Accurate . . . Battery Operated

Designed especially for humidity measurement work where a-c voltage may not be available. Under intermittent use, batteries are good for over 200 operating hours.

Range of 10-100% R.H. permits measurements of 10-50% R.H. in 1% graduations and of 20-100% in 2% graduations.

SPECIFICATIONS

Range: 10-100% R.H. (2 scales)
20-100% (2% Graduations)
10-50% (1% Graduations)
Calibration Accuracy: 2% R.H.
Power: Batteries
Battery Life: 200 hours (Intermittent)
Size: 5″ x 6″ x 7″
Weight: 6 pounds
Finish: Hammertone Gray

EL-TRONICS *Panel* HYGROMETER

Inexpensive . . . Versatile

MODEL 102

For panel mounting in industrial applications. Through external switches, any number of sensing elements, remotely located, may be connected to the meter singly.

SPECIFICATIONS

Range: 20-100% (2% Graduations)
10-50% (1% Graduations)
Calibration Accuracy: 4% R.H.
Power: 117 volts, 60 cycles
Size: 3½″ x 3½″ (Cylindrical)

EL-TRONICS *Industrial Humidity Control*

Manual or automatic . . . controls over full range 10-100% R.H.

MODEL 201 and MODEL 202

This is an electronic relay which is available in two types depending upon differential. Model 201 has a differential of ± 5% R.H. and Model 202 has a differential of ± 1% R.H. A standard thyratron tube "triggers" the relay. Contact rating is ample for electrical equipment rated up to ⅓ h.p.

SPECIFICATIONS

Range: 10-100% R.H.
Differential: Model 201—±5% R.H.
Model 202—±1% R.H.
Contacts: Double Pole, Double Throw
Current: 10 amperes
Power: 117 volts, 50-60 cycles
Size: 4″ x 4″ x 5½″
Finish: Hammertone Gray

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Please have representative call . . . . . ____

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COMPANY ____
ADDRESS ____
CITY ____ ZONE ____ STATE ____

MODEL MA640

MODEL MA2850

MODEL MA65A

RUGGED • ACCURATE • TUBELESS

MAGNETIC AMPLIFIER DC SOURCES

(MA-NOBATRONS)*

Sorensen MA-NOBATRONS* have been designed for industrial applications and unattended installations where the utmost in maintenance-free service is required.

NEW IMPROVED SPECIFICATIONS

	MODEL MA65 A	MODEL MA640	MODEL MA2850
INPUT	105-125VAC, 1Ø, 60 cycles		190-230VAC, 3Ø, 60 cycles 4-wire wye.
OUTPUT	6VDC, adj. ±10%	4.5-7.7VDC, adj.	23-32VDC, adj.
LOAD RANGE	0-5 amperes	0-40 amperes	0-50 amperes
REGULATION	± 0.2% Line or Load	± .0% For any combination of line or load	
RECOVERY TIME	0.15 seconds under worst conditions	0.2 seconds under worst conditions	0.5 seconds under worst conditions

Contact your local Sorensen representative, or write for further information. If you have special requirements in magnetic amplifier DC sources, write or call the Applications Engineering Department, and your problem will receive prompt attention.

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CONTROLLED POWER FOR Sorensen RESEARCH AND INDUSTRY

ARVID W. JACOBSON
computes for industry

In 1949 a young midwestern math professor spent his summer solving this problem for his university:

PROBLEM—creating a nonprofit computing service for industry that could also be used for education and research.

MONEY AVAILABLE—none.

EQUIPMENT ON HAND—none.

SOLUTION—a "door-to-door", podium-to-podium, selling job for mechanized mathematics that has resulted in today's largest privately-supported computation laboratory.

Dr. Arvid W. Jacobson was the man who made the Wayne University computer project move. The Doctor—he got his PhD from the University of Michigan in '48—is a compactly built, enormously friendly man deeply concerned with "people" and the relationship of his favorite subject—mathematics—to their progress and welfare. He joined the staff at Wayne in 1945 after a career that included working in the logging camps of his native northern Michigan (he quit school at 13 to become a logger and resumed his education five years later); teaching school in small towns; and hospital work (where he prime-moved an alcoholic-rehabilitation program).

Pure math—the "catalyst"

Early in his teaching career Jacobson became aware of the pressing need for more basic mathematical training for industry's engineers and scientists. He founded the "Industrial Mathematics Society"—a group dedicated to furthering pure mathematics in our industrial economy. Early work by this society unearthed a glaring need for computer facilities and catalyzed Wayne University's Computation Laboratory program.

Early in 1949 Dr. Jacobson went to MIT for a short course in computer technology. While there he talked the officials into "donating" a differential analyzer to Wayne. But once the analyzer got to Detroit the real problem arose. As Jacobson puts it, "We were immediately faced with a crying need for money simply to operate the analyzer. And when we did start, anyone could see that we needed a new and much better computer—it was obvious."

That summer Jacobson sprayed his throat, put on sturdy shoes, and "hit the road". He required $250,000 for new equipment and another $250,000 to operate the lab over a five-year period. During that hot July and August he talked to scores of local leaders in industry and business. Burroughs Corp. (rapidly developing its computer line) came through with a promise of $100,000 for equipment; General Motors pledged $150,000 and Ford came up with $50,000, contingent on the full sum being gained.

With time running out and only $350,000 subscribed, Jacobson went back to John Coleman, president of Burroughs, and laid his problems on the table. Coleman immediately pledged the remaining $150,000, and two weeks later the Computation Lab was a reality. Later, in 1953, Burroughs' UDEC computer was put into operation and the program of training and nonprofit work for industry swung into high gear.

Wayne's unique facility was a success from the start. Despite a jammed schedule, in three years Dr. Jacobson welcomed 1,200 people from industry as noncredit "students" and 750 students taking credit courses in the computing machine field. In no time at all the input and output channels to UDEC were taxed and Arvid Jacobson was busy with a new program: expansion of the first one. Expansion, basically, means more money, and Dr. Arvid Jacobson is resigned to rusting golf clubs until the small sum of $380,000 has been raised. But no one close to the project doubts his goal will be reached. As one local industrial leader puts it, "The man and the school make good sense. They plainly tell you how you can use their service and how much money you will save. And then they amortize for you the cost over the years—and, believe me, the donation is cheap at twice the price. But, best of all, they are pushing a frontier and opening opportunities for young people in a field that is vital to us as a nation."


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Control Conclaves Stir Engineers . . .

. . . HERE

In Pennsylvania, June 10-15, 183 production engineers came from busy jobs in far-flung manufacturing plants to attend a classroom and lab workshop on "Automation" at the State University. The "students" startled the "professors" with their keen interest in the engineering principles and hardware of automatic control.

At Penn State these serious, seasoned engineers eyed their future. What they saw was ➔

. . . AND ABROAD

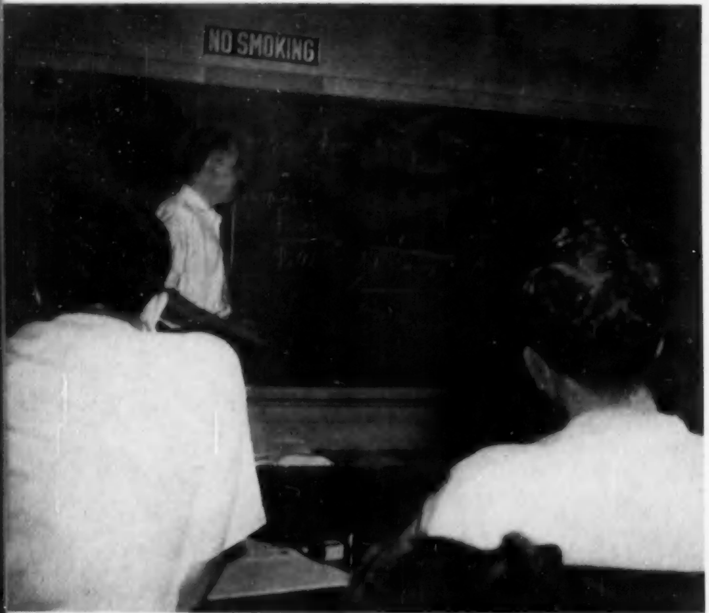
In London, May 7-18, more than 2,000 research engineers came from overseas laboratories to comb the booths of the second International Instrument Show. Although advanced test and analytical instruments were earmarked for major emphasis, the big interest centered on new devices and techniques aimed at specific industrial process and product measurements.

In London's Victoria Hall this keen trio hovered over a show-stopper. The item was ➔

As the meetings above (as well as those in Detroit, Boston, Milan, Buffalo—see June issue) suggest, Spring '56 was an active time for traveling control engineers. Wherever the locale and whatever the specific subject covered, one thing about each one of these conclaves in control is certain: it is starting to "pay off" for the attendee. Even as recently as a year ago, the issues were vague and the speakers shy on specifics and definitions. Early this year a change seemed to set in. Meeting subjects formerly labeled "Automation" got more definitive. Speakers started to furnish more facts and figures. Exhibitors appeared to know what to show and viewers seemed to know what to look for (see Editorial, page 63).

All of which is a way of saying that control engineers should keep a special eye on "conclaves to come". They are proving a good investment.

FOR CONCLAVES TO COME TURN TO PAGE 28



The visiting production engineers were watching Georg Knausenberger, a local consultant, describe a spring and dashpot system using Laplace transforms and differential equations. Comprehension of and interest in the mathematical tools of control were high.

Student Problem No. 3: Setting up an automatic weighing including two fixed and one adjustable load cycles.

Student Problem No. 6: Designing a timing program including two fixed and one adjustable load cycles.

PRODUCTION CONTROL IN PENNSYLVANIA

Student Problem No. 4: Assembling and completely calibrating a differential-transformer null-balance system.

Student Problem No. 5: Setting up a two-stop cycle vernier set timer for a repeat-cycle type of operation.

One of the most impressive things about Penn State's second annual "Automation" seminar was the type of people who attended. Study their faces on the preceding page. These are seasoned engineers—a good share of them executives—from machine tool, heavy equipment, electronics, and consumer hardgoods manufacturing plants. Their reaction to Knausenberger's control theory lecture was typical: they asked for practical examples of the math at work, wanted to know how they could use analysis—in solving an actuator design problem, for example. In other sessions (workshops with the Bellows Co., Zagar Tool, Perry Engineering, and at the 25 formal lectures, which ranged from "automatic inspection and dimension control" to operations research) they were equally sharp during question and answer periods. But they showed greatest enthusiasm when they bent over workbenches to do the six problems involving design, assembly, wiring, and testing—devised with real components and parts by Automatic Temperature Control (see pictures). This year's program was ably organized by energetic Prof. Chet Linsky of Penn State's Industrial Engineering Dept. and was sponsored by the National Association of Manufacturers in cooperation with 19 industrial firms. The fee for the seminar was $50—a modest price for a week jammed with practical instruction. Fine as the session was, however, it still lacked what almost all "Automation" conferences seem to lack: an integrated approach to the subject through basic engineering principles. But Chet advises that there will be much more tie-in to basics next year.

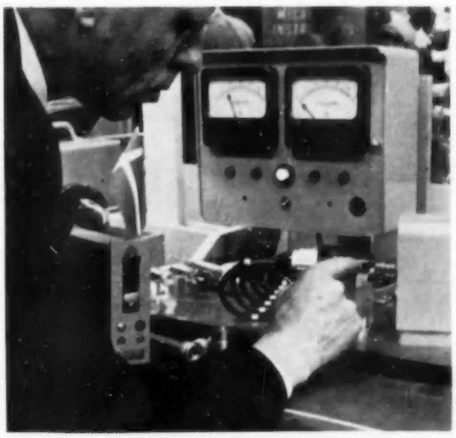
INSTRUMENTATION IN LONDON

This unique show's unusually good attendance (2,000) strongly illustrates one thing: the keen interest of engineers in equipment being designed and built beyond the borders of their own country. The exhibit was organized by B & K Laboratories, Ltd., a British firm specializing in distributing foreign instrumentation (French, German, Danish, Swedish, Dutch, and American) in England. A few other firms also exhibited, but the bulk of British instrument makers steered clear of the show. As the pictures indicate, the biggest show-stealer was Dr. Russell Varian's nuclear-parmagnetic-resonance spectroscope. Some of the world's top chemists made a special trip to see this unit perform. The first Varian NMR unit to go overseas is intended for U.K.'s atomic energy plant at Culcheth, two more are slated for Cambridge and Liverpool Universities. Other interesting items besides those in the pictures below: crane-load control equipment by Vibrometer of Switzerland (monitors job and load angle using inductive transformers); a lightweight multichannel ¼-in. tape recorder by Tolana of France (offers two channels for a-m, four for f-m); a Danish frequency spectrometer and automatic frequency response recorder (the former will record sound pressures as low as 20 db above 20×10^{-4} micro bar).

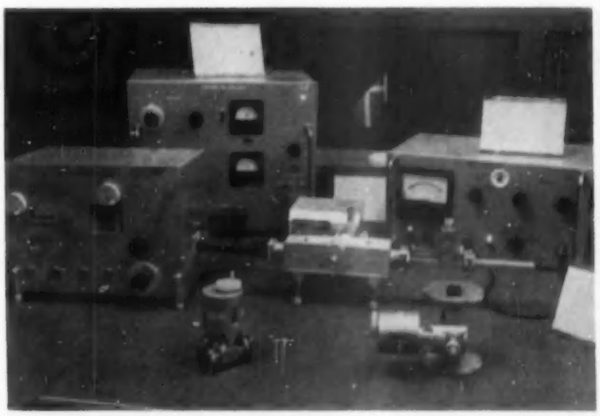
The intense trio was hovering over Varian Associates' super-high-resolution nuclear-paramagnetic-resonance spectroscope. This unit, the first to be shipped out of the U. S., was also the first ever to be put on public display. That's Dr. Russell Varian on the right.

A far view of Varian's new instrument (center rear) offers also a glimpse of the active browsing that went on through the exhibits.

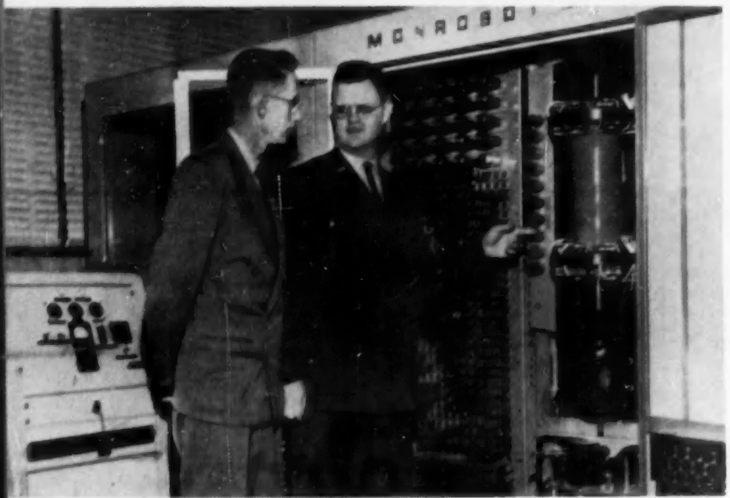
This deviation test bridge by Denmark's Bruel & Kjaer lets operator measure electronic components using actuating knee pads.



Another Danish item: an electronic tachometer using an ac generator pick-off insensitive to rotor/stator misalignment.



A Swedish entry: Sivers Lab showed this precision microwave setup with direct reading of frequency to 0.1 percent error, and an automatic standing-wave indicator system.

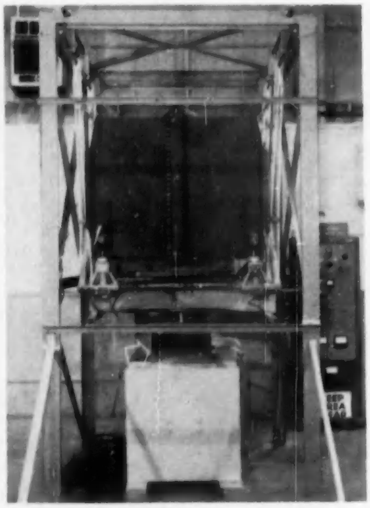


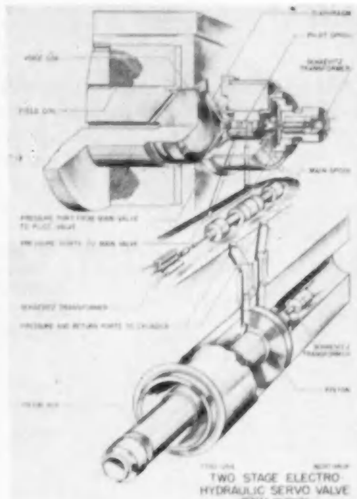
Monroe's MAID Sweeps Monrobot Clean in 30 Sec

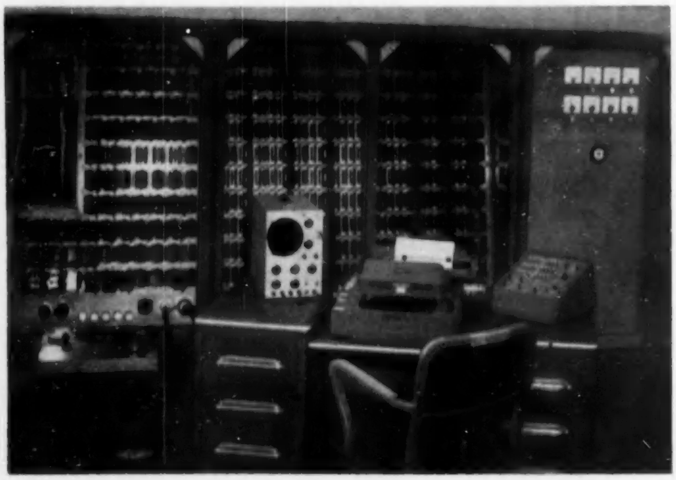
The necessary but awesome device is here—the gadget that checks computers. Thus may begin the movement in computer technology toward the device to check the device to check the device . . . to check the computer. The new arrival is the Monrobot Automatic Internal Diagnosis, or more affectionately, the MAID. She's a rugged, forthright gal who, as her name implies, isn't the slightest bit squeamish about probing around the insides of the Monrobot VI computer for failures in vacuum tubes or germanium diodes which might cause errors in computation. In 30 sec the MAID can pinpoint any trouble in the computer's 3,000 units and show where it is by means of an illuminated indicator. Looking her over are Anthony Garra, left, and Capt. Leroy E. Ross Jr., both of Wright Air Development Center.

Shaker Has Servo-Valve Heart

To test electronic components' resistance to the terrific vibrations that accompany take-off of guided missiles, Northrop Aircraft has built an electrohydraulic miniature shake-test device which will apply a force of 55 g to parts weighing over half a ton. "Earthquake Ernie" can test the effects of vibrations from 5 to 600 cps on whole airframe sections housing sensitive equipment without danger to the equipment, a decided possibility when magnetic shakers are used. The heart of the shaker (arrow in photo) is a two-stage electrohydraulic servo valve designed by Bertea Products Co. Hydraulic pressure of 3,000 psi forces "Ernie" through its $\frac{1}{4}$-in. "stroke". "Ernie" was designed specifically to test the Northrop SM-62 Snark intercontinental guided missile.

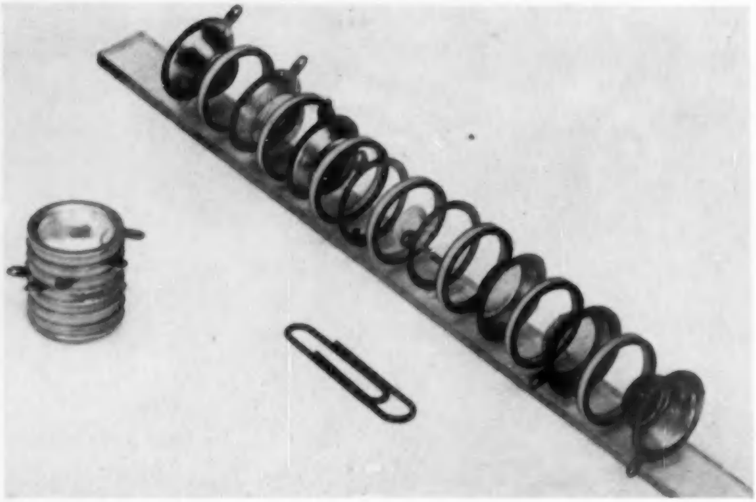






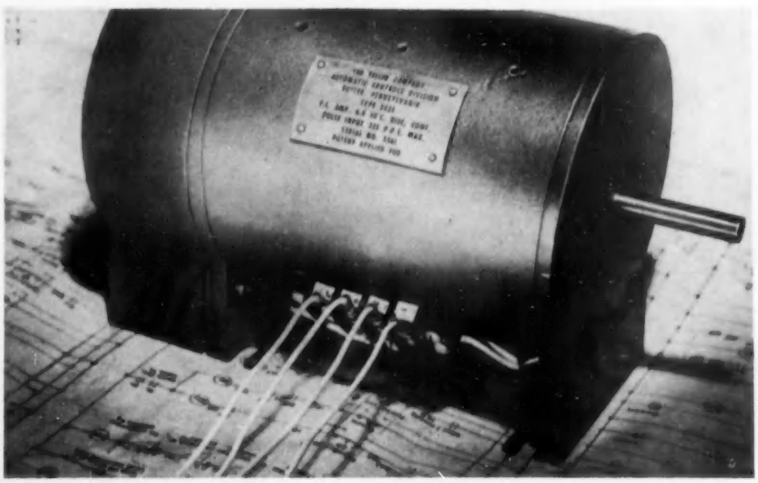
ALWAC Computer Designs Nonlinear Pot in 15 Min

An ALWAC electronic digital computer, being applied to the design of nonlinear potentiometers by Helipot Corp., cuts computation time for the average application from 32 man-hours (of engineers with desk calculators) to 15 min. Helipot engineers are often required to design a nonlinear potentiometer whose output closely approximates a given set of empirical data points. ALWAC defines a polynomial passing within the specified tolerance of the data points, smoothing out random errors. It also designs other nonlinear pots by optimizing after considering electrical and mechanical design criteria, limitations of winding equipment, etc. Eventually, Helipot intends to program pot-winding machines from output tape and even use the computer to give sales quotations.



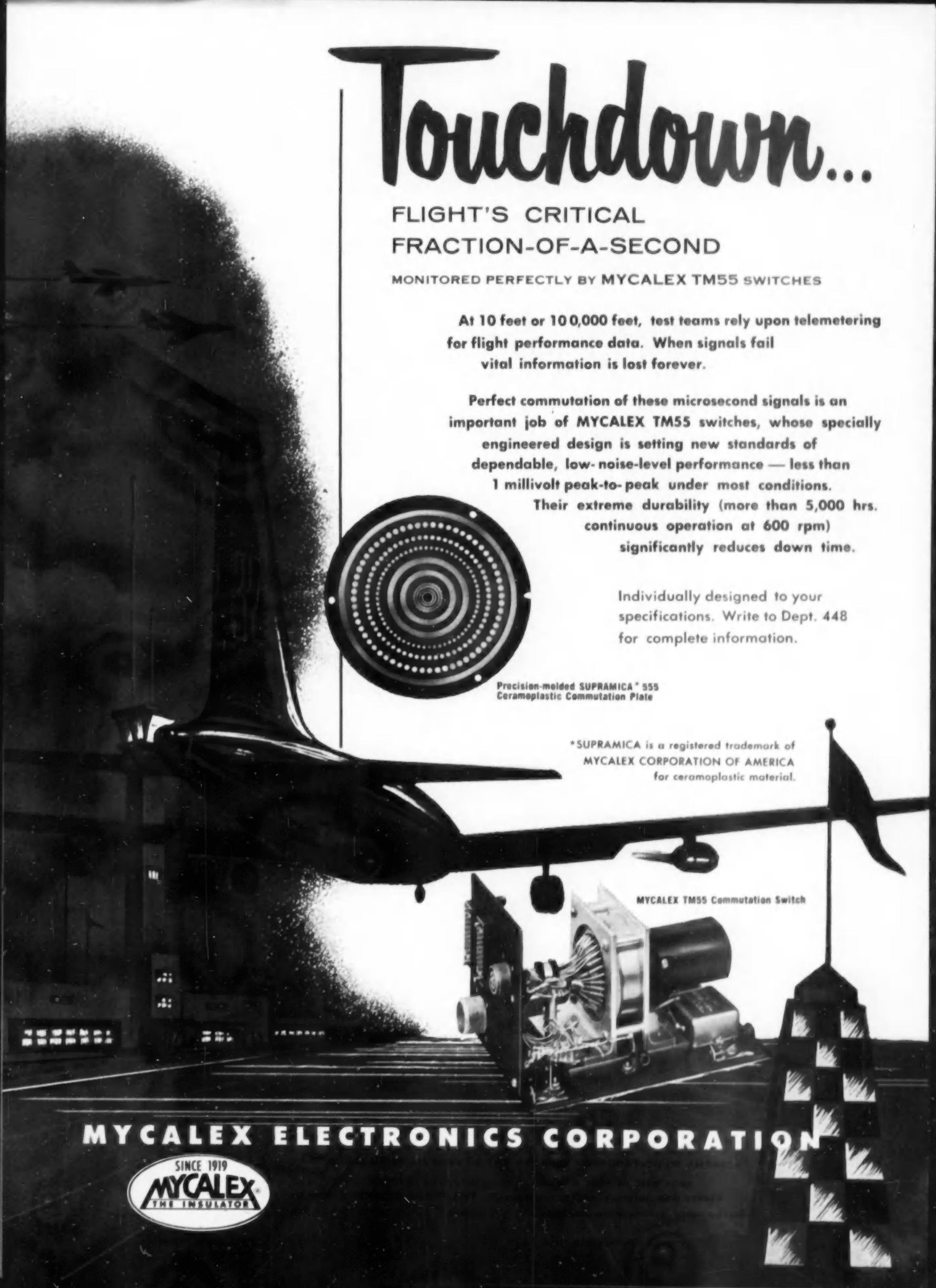
First Eimac Receiving Tube Is Precision Ceramic Model

Does your application need a tube that will not produce spurious outputs when accelerated at several hundred g's? Or one that will give high performance for thousands of hours at 400 deg C? Eitel-McCullough claims to have the answer in their new line of ceramic vacuum tubes, which also represents Eimac's first venture into the receiving-tube field. The 33C3A2, shown whole and exploded above, is a dual triode, similar electrically to the 6SN7, but with somewhat higher inter-electrode capacities. It is rated to operate continuously with an envelope temperature of 300 deg C, and should have a life expectancy of 20 to 25 thousand hours. The fact that no resonances could be found in the range from 10 to 3,000 cps at accelerations up to 30 g, the limit of available vibration test equipment, further attests to its mechanical ruggedness.



This Package Converts Pulses to Torque

Here's a unique little digital actuator—just announced by the Teller Co. of Butler, Pa.—that can simplify the design of many a control system. Basically, it's a step motor with patented refinements which equip its rotor to respond to pulse inputs originated by tape or punch-card programs. It can handle up to 325 pps and is available in outputs ranging from inch-ounce of torque to thousands of inch-pounds. Hence it offers an interesting, accurate means, for, among other things, directly driving a proportional valve or positioning a device in an open-loop system without requiring a feedback or error-correcting signal. The unit is the first commercially available component of a machine control system described in CONTROL ENGINEERING in February 1955, page 13.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FRACTION-OF-A-SECOND
MONITORED PERFECTLY BY MYCALEX TM55 SWITCHES
At 10 feet or 100,000 feet, test teams rely upon telemetering for flight performance data. When signals fail vital information is lost forever.
Perfect commutation of these microsecond signals is an important job of MYCALEX TM55 switches, whose specially engineered design is setting new standards of dependable, low-noise-level performance — less than 1 millivolt peak-to-peak under most conditions. Their extreme durability (more than 5,000 hrs. continuous operation at 600 rpm) significantly reduces down time.
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WHAT'S NEW

CONTROL CONCLAVES TO COME

Morgantown, Aug. 27-29

Once again the School of Mines in West Virginia U. will hold its annual Appalachian Gas Measurement Short Course on the application, operation, and repair of natural gas measuring and pressure regulating equipment. Coincidental will be an exhibit by 45 gas equipment manufacturers. General chairman in this 19th annual meeting is Howard S. Bean of the National Bureau of Standards. For more details contact, Prof. R. E. Hanna of the university faculty.

New York, Sept. 17-21

Last year's special University Exhibit of control developments at the Production Engineering Show (CtE, Nov. 1955, p. 24) was so rewarding to viewers and exhibitors alike that a similar display will be a feature of the forthcoming Instrument Society of America conclave in the new New York Coliseum. At this date the exhibit—co-sponsored by CONTROL ENGINEERING and ISA — includes items from nine eastern universities:

Cornell—dynamic load analysis of journal bearing motion

Johns Hopkins U.—a fermentation rate indicator; a demonstration of nervous-system wave forms, and apparatus for deforming and studying metallic crystalline structure

MIT — a dual-function generator and an intriguing new method for graphically simplifying the dynamic flow characteristics of a process

Pennsylvania State U.—two items, consisting of a compact temperature controller capable of 1/50 deg F per-

CORNELL's exhibit last year showed how variables influence journal bearing performance. This year the display will focus on dynamic load analysis of similar bearings.

The Pot That "*Failed*" Proved BORG Reliability

Borg Model 205 Micropot Operated Satisfactorily Up to 70 Gs!

A BORG CUSTOMER* *(with a sense of humor)* WAS ON THE PHONE . . .

"Your model 205 Micropot failed on test."

"What test?" we asked.

"We vibrated it over an extremely wide range 0 to 500 CPS and that 205 Borg Micropot operated satisfactorily up to 70 Gs. Then it failed."

"Did you say 70 . . . seven zero Gs?"

"I certainly did. Please forgive my kidding you a little and tell me something. How can you build an item of such precision that will withstand the terrific punishment of vibration shocks 70 times the acceleration of gravity? What holds the resistance in place? Do you glue it in?"

We answered, "Better than that. We encapsulate it in the housing. The resistance winding is positioned on a very accurately ground steel mold core. End leads and terminals are soldered on and the whole assembly is molded into a unit contained in the bakelite housing. This is an exclusive advantage of Borg Micropots. Only Borg does it this way."

"Now I understand how you get that permanent reliability. But how do you guide the contact to retain such accuracy right up to the point where the structure fails?"

"Here again is an exclusive Borg advantage", we told him. "The contact is guided over the resistance helix by a precision-ground lead screw so that only the contact touches the sensitive element. This lead screw is integral with the mounting surface so concentricity is built-in for life.

"Incidentally, the new 900 Series Micropots have a hollow lead screw to allow two or more units on a single shaft. This eliminates mis-phasing and sloppy drives."

"O.K., I get that", said our customer, "but will you guarantee your Micropots for 60 Gs vibration?"

This was the curve he'd been waiting to throw us. We said, "While most of our 900 Series Micropots will probably meet such a requirement, we won't guarantee it. However, we *will* guarantee them to meet all the requirements of MIL-R-12934. Your own evidence that Borg Micropots withstood 70 Gs vibration is just further proof of the large safety factor built into all Borg Micropots for reliability and long life."

*Name supplied on request.

Write for Complete Engineering Data

BORG EQUIPMENT DIVISION
THE GEORGE W. BORG CORPORATION
JANESVILLE, WISCONSIN

Built by Borg

AN OPTIMIZED GAS BURNER proved a popular demonstration in the Ohio State booth at last year's University Exhibit in Chicago. It combined servo and digital techniques.

formance, and a ferroelectricity analyzer

Princeton—an electrochemical servo, including nonlinear combination networks to modify the servo output

Rensselaer Polytechnic Institute—a three-model control self-balancing scale; a pneumatic panel process simulator, and an all-electronic servo function analyzer

Tufts—a meter which measures the force of human bite action; a servo-anesthetizer

Yale—a gyro stablized monorail car and an equipotential field plotter

Following the pattern set last year, CONTROL ENGINEERING will carry complete reports on most of these university items in its September issue. A meeting has been planned wherein engineers manning the exhibits, and their professors, can exchange ideas with each other, as well as with the editors of CtE and officials of ISA. If any readers are particularly interested in the problems and trends in school activity in control engineering and who would like to attend this session, please write to Chief Editor Bill Vannah—sufficient interest could enlarge the session into a special panel discussion of education in our field.

Heidelberg, Sept. 25-29

A recent letter from Prof. Rufus Oldenburger (see *Important Moves by Key People*) indicates that he will travel to Germany this fall to speak at an International Conference on Modern Theories of Control and their Application. Rufus will speak on the "major mathematical theories that have found application in the field of automatic control".

Other morning speakers: Dr. K. Küpfmüller (said to be the first man to use closed-loop diagrams) on "Mod-

ern Theories of Automatic Control", and J. M. L. Janssen on "Theory and Application of Elementary Techniques in the Science of Automatic Control". A total of 77 papers—organized into 14 sessions—will follow these introductory talks. Prof. Oldenburger says they "are scheduled to cover in detail such topics as instruments and instrument engineers, the dependability of mathematical models for control systems, the state of automatic control in Germany, and the future of the automatic control field". The conference, co-sponsored by the German Society of Mechanical Engineers and the Germany Society of Electrical Engineers, will include 34 papers by Germans, 18 by Americans, seven from Great Britain, four apiece from Switzerland and Japan, three each from Sweden and Holland, two from the Soviet Union, and two from Austria, and single contributions by engineers from Italy, France, and Yugoslavia. Among the Americans on the program: Dave Boyd (Universal Oil Products); Remus Bretoi (Honeywell's Aeronautical Div.); Porter Hart (Dow Chemical); Bob Kochenburger (U. of Connecticut); Hank Paynter (Pi Square Engineering); Jim Reswick (MIT). All in all, this appears to be one of the most complete and authoritative conclaves on control engineering ever scheduled. Dr. Oldenburger reports that "five Russians from the Institute of Automatic Control and Telemechanics in Moscow plan to attend the Heidelberg conference". (For Russia's attitude toward automatic control, see *Industry's Pulse*, page 57.)

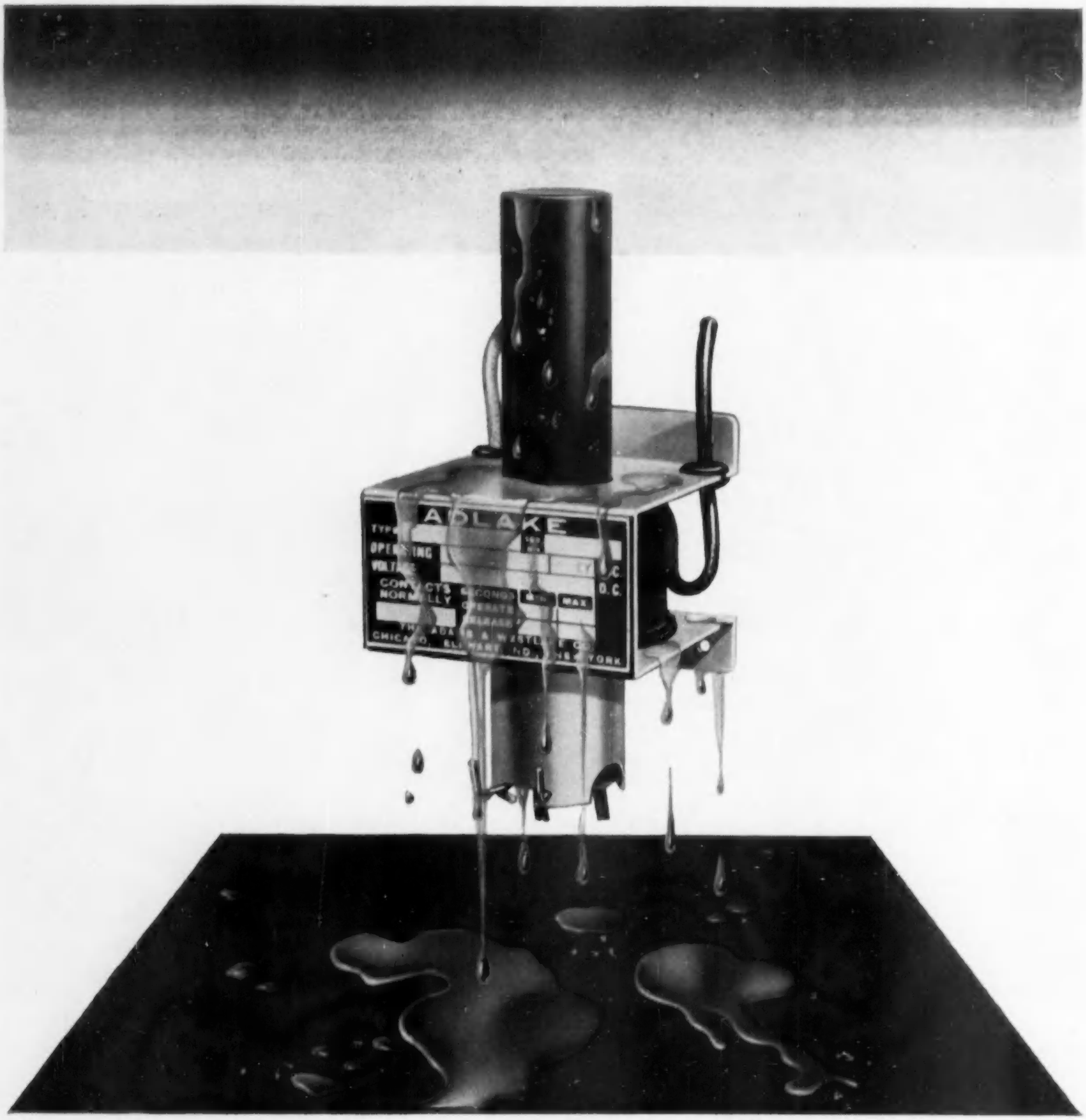
Chicago, Oct. 1-3

A record 240 commercial exhibits and 100 technical papers will liven up the rooms and corridors of the Hotel Sherman during this 12th annual National Electronics Conference. Sponsored jointly by IRE, AIEE, Illinois Institute of Technology, U. of Illinois, and Northwestern U., the conclave is expected to draw 10,000.

All Around the Business Loop

► In 1946, when A. Donald Booth and William N. Locke first proposed computer translation of languages, the proper equipment was not available. But as enthusiasm grew and more

(*Continued on page 134*)



If moisture troubles your controls . . . it'll pay you to use

Adlake mercury relays

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Sept. 17 to 21, 1956

Adlake relays require no maintenance whatever . . . are quiet and chatterless . . . free from explosion hazard. Dust, dirt, moisture and temperature changes can't affect their operation. Mercury-to-mercury contact gives ideal snap action, with no burning, pitting or sticking. Time delay characteristics are fixed and non-adjustable.

For more information about Adlake Relays, write The Adams & Westlake Company, 1181 N. Michigan, Elkhart, Indiana

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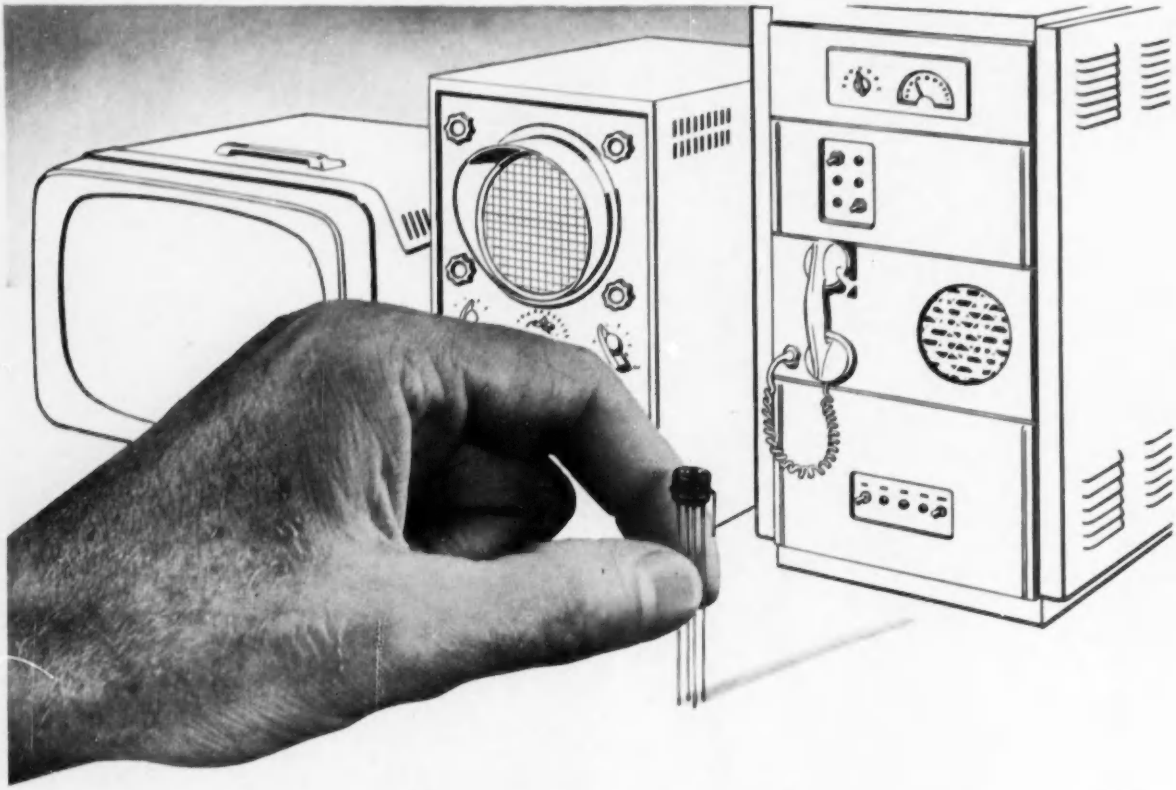

New General Electric Tetrode Transistor Amplifies at 120 mc

The new General Electric Germanium NPN Tetrode has been designed for amplification, switching, controlled oscillation, AGC, and other higher frequency operations

Meltback process, new package design. Higher frequency operation is made possible by recent G-E developments of the meltback process. Exceptional results obtained from devices produced through this process have led to the design of this new transistor. A new standard package design provides easy adaptation to printed circuit applications, an extra lead for grounding when used at higher frequencies, good heat dissipation, and a more convenient smaller size.

In Television Circuits: This transistor used in a six-stage TV IF amplifier operates at a center frequency of 45 mc. Maximum bandwidth in each tank circuit can be obtained with a variable inductance which resonates with the transistor and circuit capacitance. This tetrode amplifier delivers up to 57 db gain with a 4 mc bandwidth. A video amplifier of two stages, each containing a tetrode—produces a power gain of 33 db $\pm$.4 db from 30 cps to 10 mc which is equivalent to vacuum tube performance.

In Radar Circuits: The new tetrode has been used in a standard radar IF amplifier. Operation showed a 70 db power gain at 30 mc with a 3 mc bandwidth.

In Oscillator Circuits: An oscillator operating at 110 mc produced a 10 mw output power.

In Pulse Circuits: A typical circuit with a pulse repetition rate of 1 mc has a peak pulse power gain of 10 db. The output pulse has a rise and fall time of 0.025 microseconds and a pulse width of 0.07 microseconds.

Four Typical Tetrode Specifications Are:

Collector Voltage	—	7 volts
Power Gain	—	10 db min. at 120 megacycles
Bandwidth	—	2 megacycles
Power Dissipation	—	50 milliwatts at room temperature

Ask your General Electric Semiconductor Specialist for the full details and technical specifications. Or, write today to: *General Electric Company, Section X9986, Semiconductor Products Department, Electronics Park, Syracuse, N. Y.*

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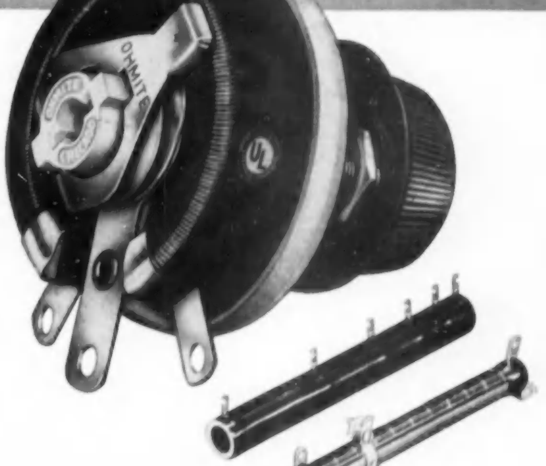

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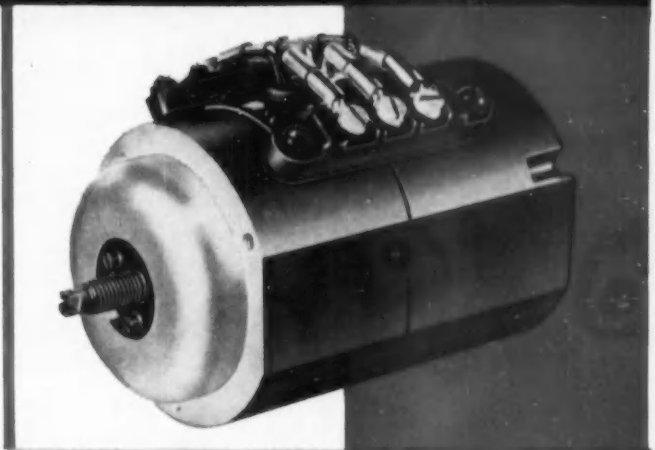
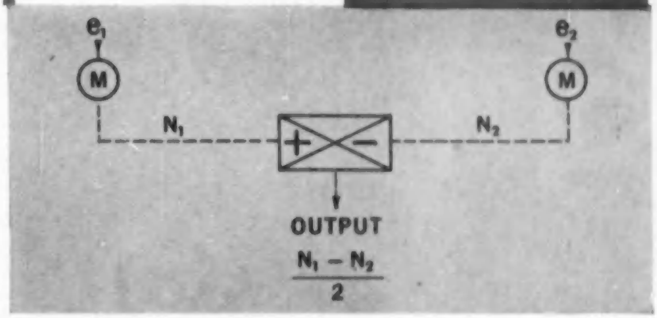


KOLLSMAN

synchronous differential

... in production



- compact—only 2⅜ x 4¼ inches.
- lightweight — 28 ounces.
- inherently accurate — driven by synchronous motors
- for many 60 cycle and 400 cycle applications
- operates from single or polyphase sources
- maximum torque — 1.0 oz./in.

Kollsman's control engineering specialists are ready to work with you on your specific application. Write for information today and tell us your needs.

in one package—a half-speed synchroscope with High Sensitivity plus $\boxed{\textit{usable torque}}$

This versatile half-speed synchroscope mates two tiny hysteresis-type synchronous motors of variable frequency, with an unusually efficient differential gearing system—all in one compact unit. The output shaft rotates at a speed equivalent to ½ the difference between the speeds of the two synchronous motors.

Thoroughly tested and perfected for military use, the Kollsman precision SYNCHRONOUS DIFFERENTIAL is now available for a wide range of commercial applications in speed and position control, flow control in process industries, and computer applications — to suggest but a few.

CAREER OPPORTUNITIES: *We have openings for mechanical and electro-mechanical engineers and senior technicians. Write us if interested.*

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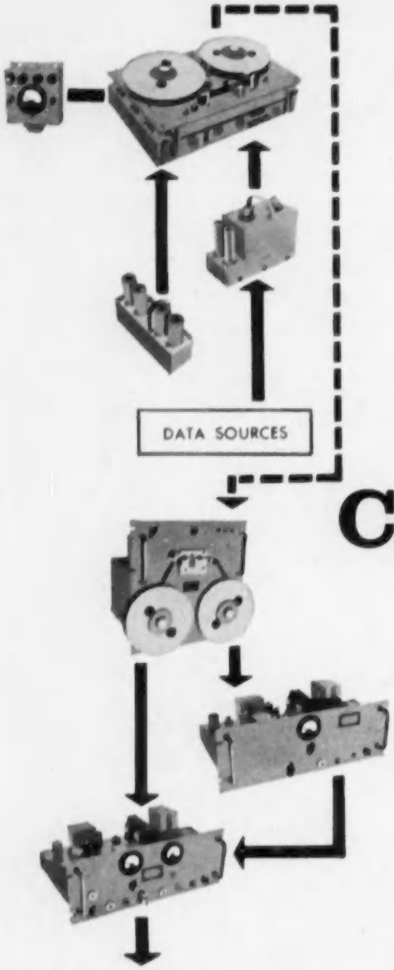

In choosing data recording equipment, it is now feasible to tailor the equipment to present and future data handling needs. It is no longer necessary to tailor your entire program to equipment limitations.

Choosing A System

for magnetic tape DATA recording

When magnetic recording was in the audio phase of its development, there was just one recording method—direct recording. But today, several methods are available. And while direct recording is still common in audio work, it has taken a back seat to modulated carrier techniques in the more critical field of *data* recording.

To take advantage of the broad range of equipment and techniques now available, start with a thoroughgoing analysis of your own present *and future* data handling . . . data processing needs. Then, match the techniques and individual components *to those needs.*

Choose the recording method first: Direct recording is limited in data work by its poor amplitude reproduction and poor low frequency response on playback. Pulse width modulation (PWM) recording is excellent for recording a large number of channels with limited frequency response. Digital recording offers extremely high data accuracy, but relatively low information capacity.

FM recording, electronically compensated for wow and flutter, offers a combination of high overall system performance, frequency response, and information capacity, suiting it for most analog recording applications. Any or all of these methods can be supplied in the same recording system by inserting the proper plug-in circuitry.

Consider physical requirements next: Where you plan to use a system is an extremely important factor. To record data in a missile or jet, you will obviously need different equipment than would be used in a laboratory. But reel size, tape width, tape speeds, must also be selected. And heads, available for recording from 2 to 24 data tracks or even more, should be specified early. Keep in mind also the planned final disposition of the data, whether to a computer, direct writing recorder, or other equipment.

Finally, select system components and accessories: In FM carrier recording alone, you can choose from at least three recording oscillators, two reference generators, and several signal and compensation discriminators. Speed control servos, power supplies, and remote controls also require attention.

Needless to say, much of this process of selection requires special experience, and should be placed in the hands of the competent data recording systems manufacturer. But the important thing to remember is that data recording on tape is a field in itself, with special techniques and special equipment that can be matched to virtually any recording need. The day when the problem had to be tailored to the equipment is long past.

More detailed information on recording systems and equipment, and how to select them, is provided in "The Role of Magnetic Tape In Data Recording," available on request to Davies Laboratories, Inc.

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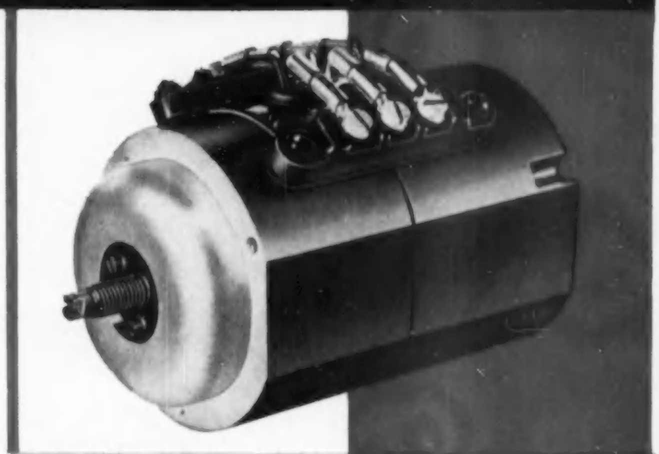

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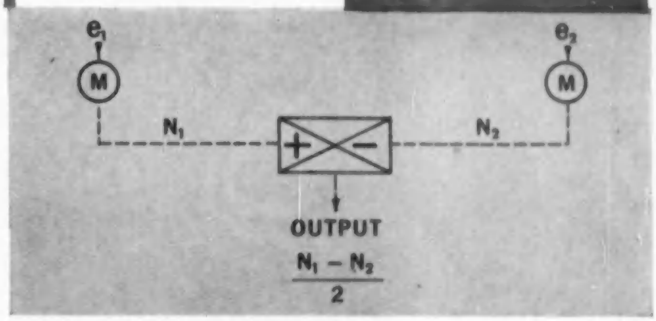
synchronous differential

. . . in production

- compact—only 2⅜ x 4¼ inches.
- lightweight — 28 ounces.
- inherently accurate — driven by synchronous motors
- for many 60 cycle and 400 cycle applications
- operates from single or polyphase sources
- maximum torque — 1.0 oz./in.

Kollsman's control engineering specialists are ready to work with you on your specific application. Write for information today and tell us your needs.



in one package—a half-speed synchroscope with High Sensitivity plus $\boxed{\textit{usable torque}}$

This versatile half-speed synchroscope mates two tiny hysteresis-type synchronous motors of variable frequency, with an unusually efficient differential gearing system—all in one compact unit. The output shaft rotates at a speed equivalent to ½ the difference between the speeds of the two synchronous motors.

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CAREER OPPORTUNITIES: *We have openings for mechanical and electro-mechanical engineers and senior technicians. Write us if interested.*

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From MOOG . . . **a Dual Input Servo Valve for Flight Control**

Pilot boost servos for control surface positioning are commonplace. These servos are usually necessitated by high control surface aerodynamic loads which make direct control through the pilot's stick impracticable. Generally, they are mechanical-hydraulic in nature.

Today, as aircraft operational requirements increase, it is necessary to add artificial flight stability augmentation through these servos. Also, aircraft autopilots must work through this medium. These modes of operation generally require electro-hydraulic servos.

To coordinate these functions, the Moog Valve Company introduced, and is now in full production on, its Dual Input Servo Valve. These units permit direct mechanical-hydraulic flight control, combined mechanical-hydraulic and electro-hydraulic control, and electro-hydraulic control alone. Full mechanical override for safety is always possible and self-contained solenoid and lock-out arrangements permit full flight mode selection.

Employing an entirely new principle of summation, the Moog units accomplish the electro-mechanical mixing function without linkage in a single, integrally-designed package. By elimination of linkage inertia and backlash, the Moog Dual Input Valve greatly increases low amplitude resolution and frequency response. It simplifies the entire control system and is far more compact than other dual input mechanisms.

The Dual Input Servo Valve was developed by Moog's creative engineering staff. This team approach is available to industry to produce advanced electro-hydraulic servo components.

MOOG VALVE CO., INC., PRONER AIRPORT, EAST AURORA, N.Y.

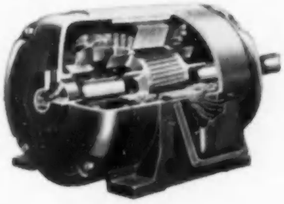
MOOG

STOP

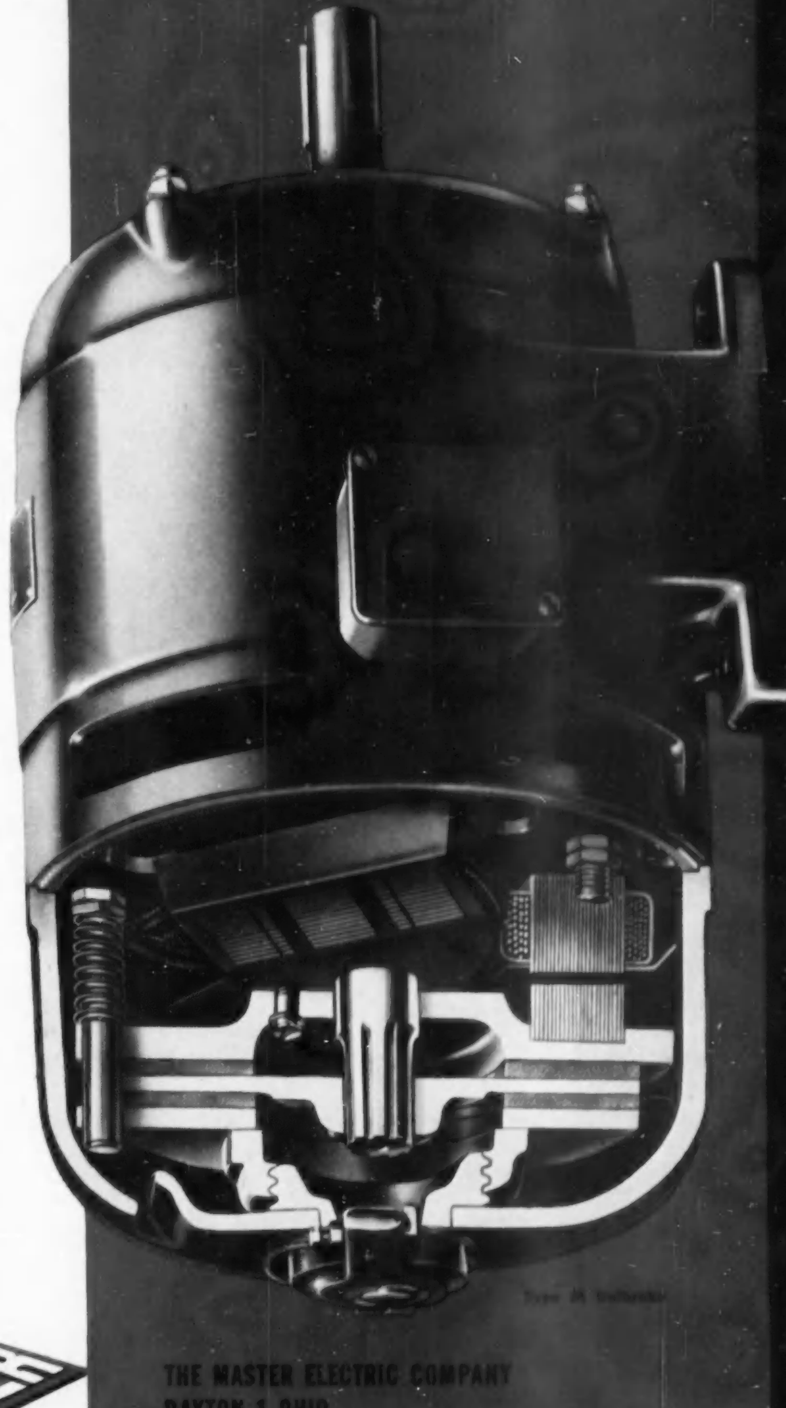
TWO WAYS...with Master Unibrakes

STOP-HOLD—Master Type M Magnetic Unibrake Motors. For quick, controlled stopping—especially when you want to hold the load. Spring-setting magnetic release brakes of the friction disc type combine with motor in a compact, integral unit. Sizes—1/8 to 150 H.P.

ROLLING STOP—Master Type D Dynamic Unibrake Motors. Braking is obtained with a unique, patented brake winding superimposed on the stator winding. Simple, compact, with no DC current required, the brake has no moving parts. There is nothing to wear or adjust—braking torque repeats consistently. Particularly recommended for automatic applications which do not require static holding. Sizes up to 30 H.P.



MASTER GEARMOTORS and variable speed drives can be supplied with integrated Unibrakes too. See Master for the perfect power drive for you.



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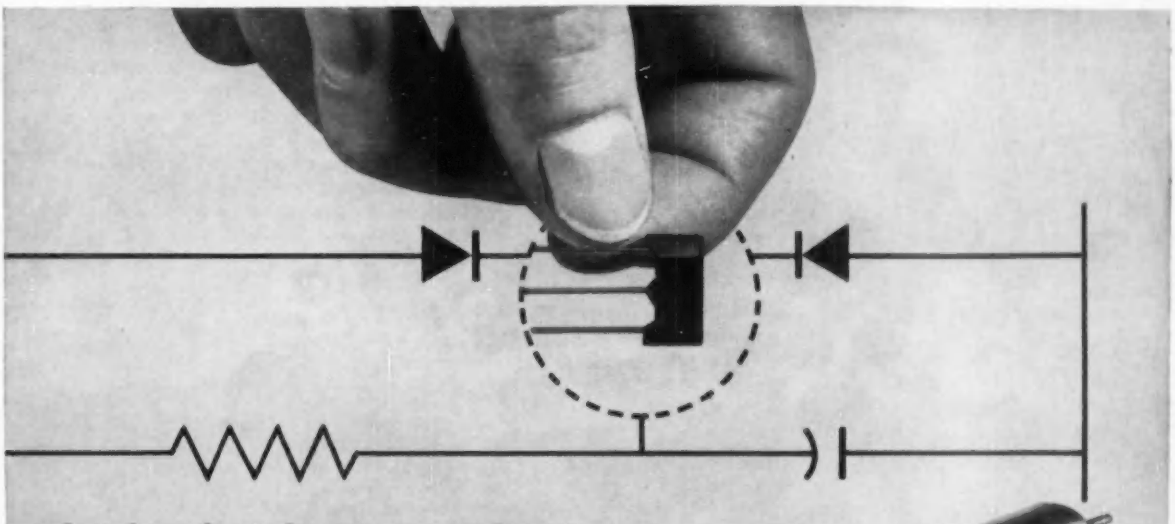
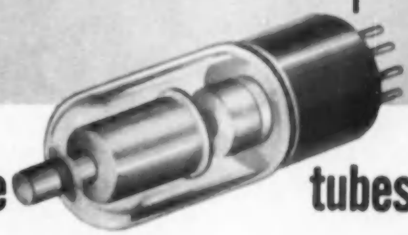
MASTER UNIBRAKE MOTORS



Look what happens when

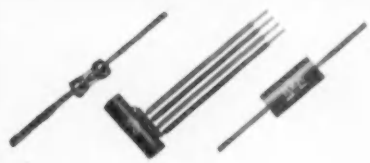


MICROSTAK diodes replace tubes

By replacing dual diode vacuum tubes with MICROSTAK Selenium Dual Diodes, you can now save space and money in many low current applications calling for high back resistance and low forward resistance. These IRC components not only eliminate all the added bulk, sockets, and assembly connected with tubes, but are also economical to buy and use.

MICROSTAK Selenium Dual Diodes cover a microampere to milliampere current range at voltages as high as several thousand volts. Furthermore, they are available in molded plastic, hermetically sealed glass, and other enclosures. As a result, MICROSTAK Selenium Diodes deliver the performance you want in power supplies, voltage regulators, balanced modulators, arc suppression, meter overload protection, logarithmic converters, magnetic amplifiers, and many other applications.

FEATURES OF MICROSTAK DIODES



- Available in single or multiple cell types
- Excellent performance at ambient temperatures up to 125° C.
- Supplied to much closer limits than ordinary diodes
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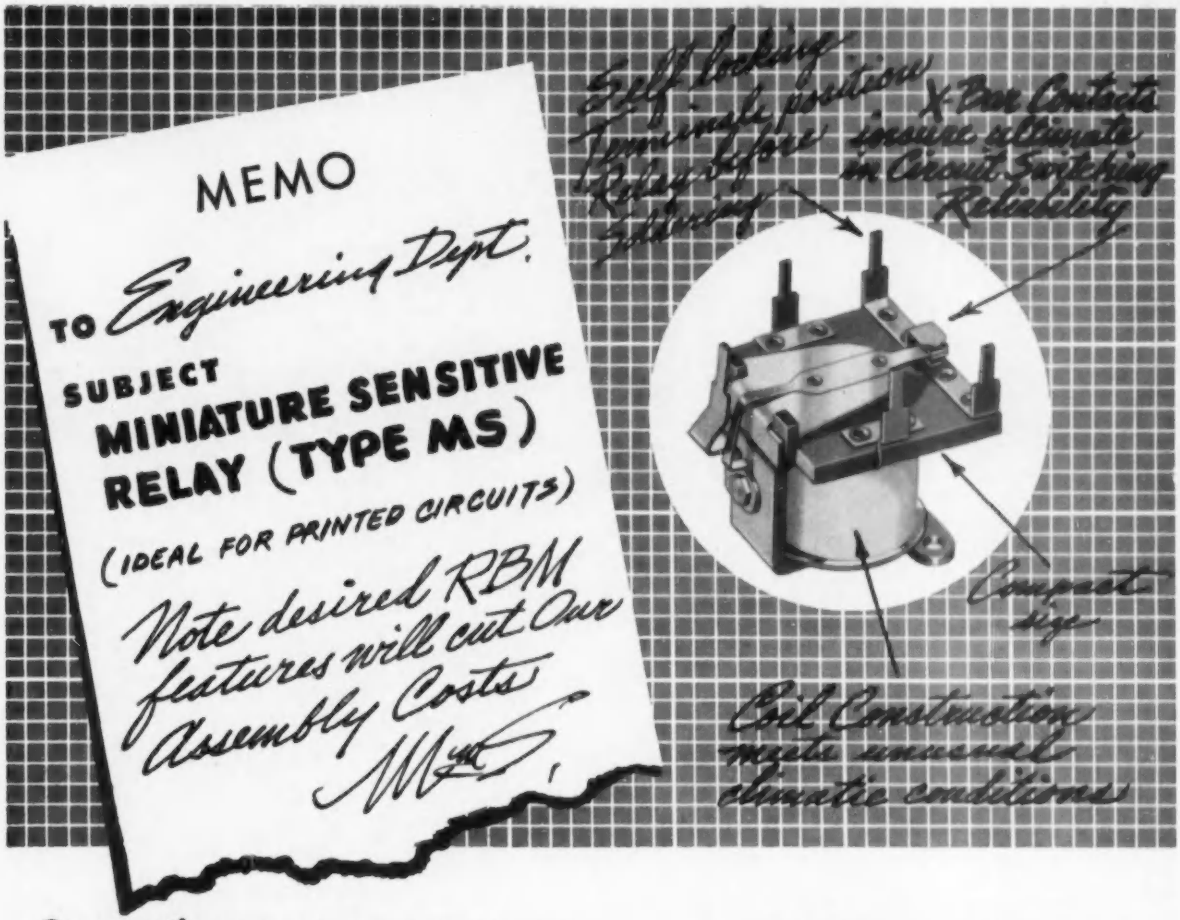
Wherever the Circuit Says

IRC

Low Wattage Wire Wounds • Resistance Strips and Discs • Selenium Rectifiers and Diodes • Hermetic Sealing Terminals • Insulated Chokes • Precision Wire Wounds.



Construction—Printed circuit terminals are designed with snap-in feature which holds relay in printed circuit board without lugging prior to solder dip.

Other versions of MS relay available with standard solder type terminals and insulating base, where required. Also with 4 N.O. isolated circuits having common make.

While not yet in production, extra-sensitive version has been developed. Maximum coil resistance 18,000 ohms, nominal sensitivity .030 watt, maximum sensitivity .020 watt, overall height 1-9/16". All other details same as standard MS relay.

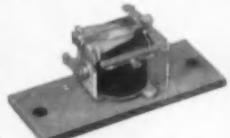
Application—Type MS is an ideal relay for any application requiring a compact, highly reliable single pole D. C. device, where a low cost solution is required because of volume usage and competitive problems.

The fact that industry has already used over a million units of this design is your assurance that the R-B-M Type MS relay will meet your most exacting requirements.

Contacts used in Type MS are of the cross bar type, which offer the ultimate in reliability throughout the life of the relay. Molded bobbin design has eliminated coil failure on sensitive applications under severe climatic conditions.

OTHER VERSIONS


SOLDER TERMINALS
4 isolated circuits with common make contact.


INSULATED BASE
Solder terminals mounted on insulating base.


EXTRA SENSITIVE VERSION

ENGINEERING DATA

Specifications	Miniature Sensitive Relay Type MS
Contact Form	S. P. D. T.
Contact Rating	1 amp. 32 V.D.C. non-inductive
Coil Resistance	Up to 10,000 ohms
Nominal Sensitivity (Coil Input)	.060 Watt
Maximum Sensitivity	.040 Watt
Approx. Dimensions	1-1/8 x 1-1/16 x 1-1/32"

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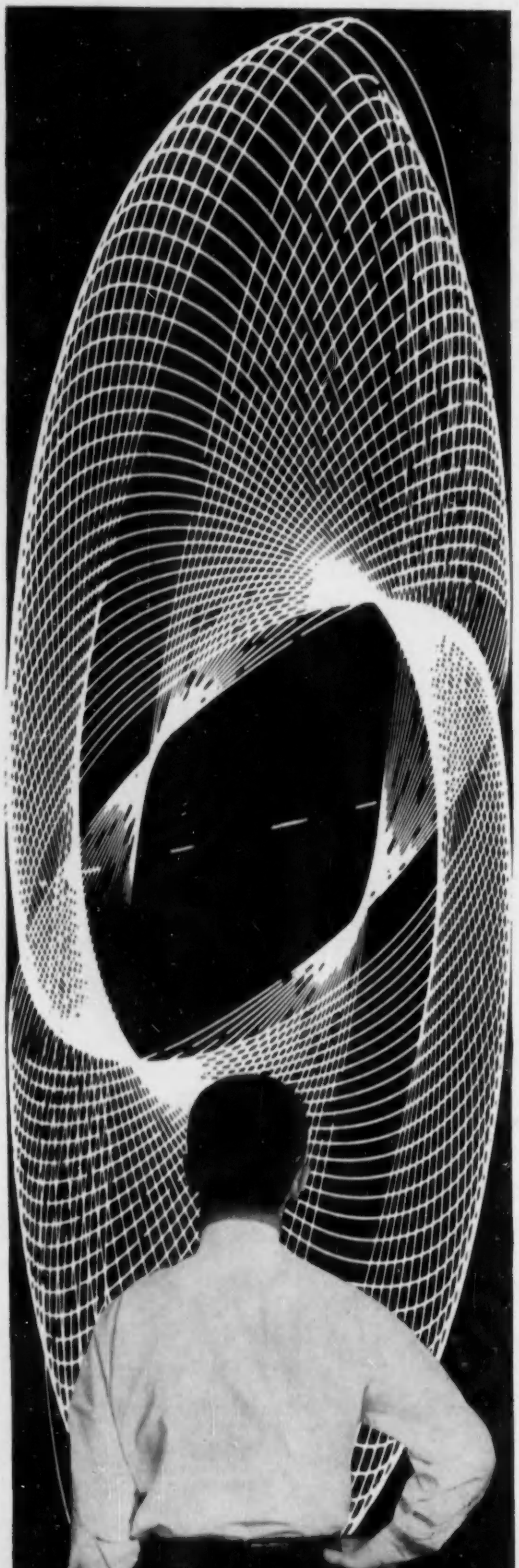

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Today at AUTONETICS there are elaborate automatic control systems actually being developed, designed and *produced* in quantity that make the mechanics of the wildest space fantasies look ordinary.

For example, where in the pages of science-fiction is there a robot that compares with AUTONETICS' new airborne digital computer? This 3-cubic-foot brain can solve mathematical problems in one second that would take a math whiz with pencil and paper 9 hours, or require a clothes closet full of ordinary computer equipment. It can continuously integrate 93 quantities simultaneously . . . through 51 removable panels of etched, transistorized circuitry.

This is only one example of AUTONETICS' far-reaching electro-mechanical technology. There are hundreds of other areas of equally advanced opportunity in missile guidance, flight control, fire control and special automatic controls. Among your tools are the latest data processing equipment, plus modern and complete environmental and flight test facilities. AUTONETICS' scientific leadership is setting the pace in this field with its unique 10-year backlog of know-how.

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CHEMICALS
- ☐ Pumps
- ☐ Conveyors
- ☐ Process Machinery
- ☐ Winders

FOOD PROCESSING
- ☐ Mixers
- ☐ Dryers
- ☐ Conveyors
- ☐ Mills

GRAPHIC ARTS
- ☐ Main Presses
- ☐ Press Auxiliaries
- ☐ Winders
- ☐ Slitters

MATERIALS HANDLING
- ☐ Conveyors
- ☐ Cranes
- ☐ Shovels
- ☐ Lift Trucks

MINING
- ☐ Conveyors
- ☐ Hoists
- ☐ Mills

METAL WORKING
- ☐ Rolling Mills
- ☐ Presses
- ☐ Winders
- ☐ Slitters
- ☐ Loop Cars

PULP AND PAPER
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- ☐ Auxiliary Helpers
- ☐ Converting Machines
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RUBBER AND PLASTICS
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- ☐ Plasticizers
- ☐ Calenders
- ☐ Winders

TESTING
- ☐ Engines
- ☐ Pumps
- ☐ Motors
- ☐ Auxiliaries
- ☐ Wind Tunnels

TEXTILES
- ☐ Winders
- ☐ Slashers
- ☐ Dryers
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- ☐ Fans
- ☐ Boiler Feed Pumps
- ☐ Feeders

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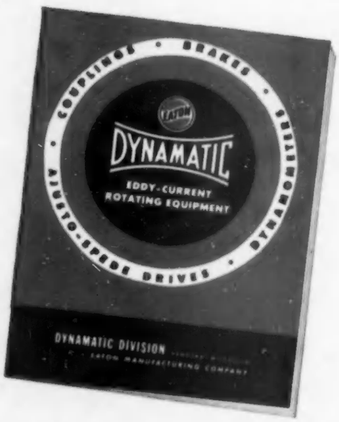
Using standard AC lines as a power source, Dynamatic torque transmitting equipment satisfies most stepless adjustable speed requirements. Dynamatic Ajusto-Spede® and Dynaspede® Drives, Couplings, Brakes, and Dynamometers with electronic or magnetic amplifier control provide the advantages of rapid response, wide speed range, quiet operation, low power losses, low maintenance cost, and remote control.



Send for your free copy of the Dynamatic Bulletin GB-2, which illustrates and describes eddy-current adjustable speed rotating equipment.

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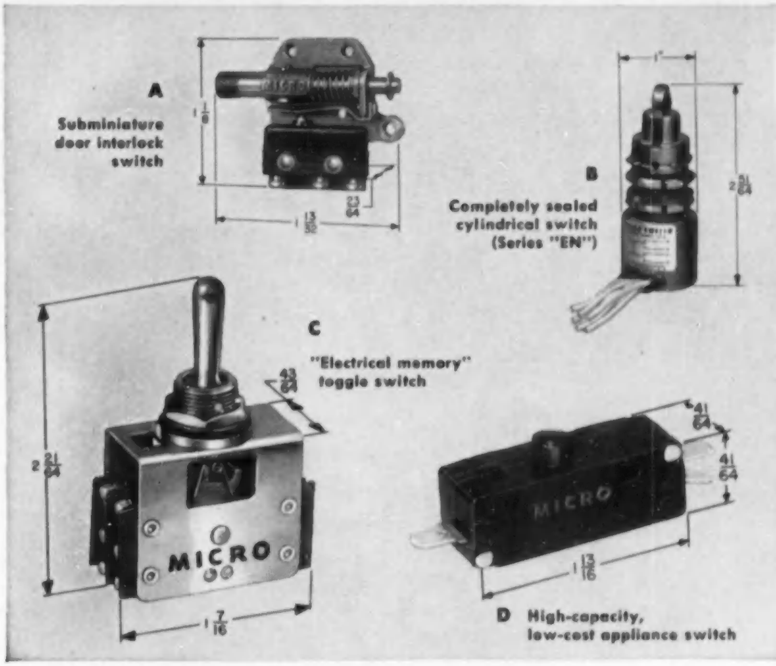
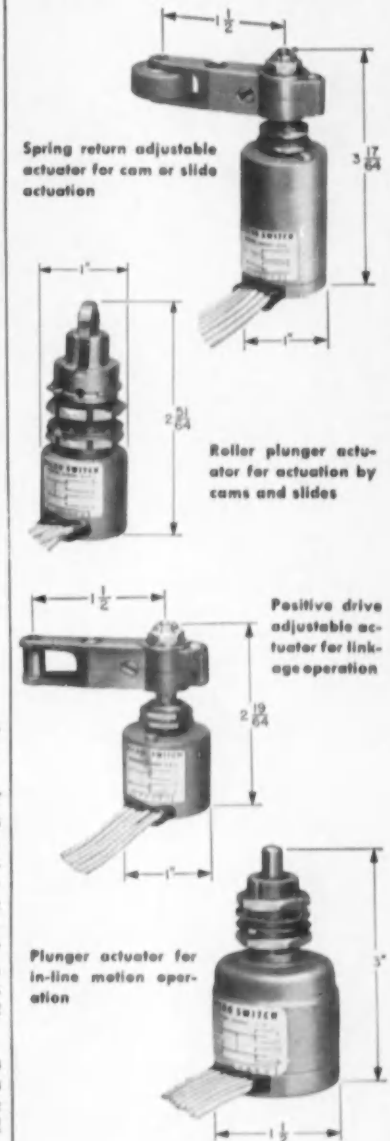
MICRO precision switches

...THEIR USE IS A PRINCIPLE OF GOOD DESIGN

HONEYWELL



See the unusual design flexibility of the new MICRO Series "EN" switches



A continuous flow of Precision Switch Developments anticipates Your design needs

MICRO precision switches are developed and built to meet specific requirements. Some designs call for the utmost precision, plus reliability. Other designs put long life and extreme reliability at the top of the list. Some must have all of these and more. Whatever YOUR requirement may be, MICRO SWITCH has a switch readily available or can work with you in its development.

Here are a few recent MICRO SWITCH *developments to meet specific needs:*

A The subminiature door interlock switch is for use where an extremely small assembly is desired to provide automatic cut-off of the power circuit when a cabinet door is opened. This switch assembly has been found extremely valuable on radio, radar, x-ray and other hazardous equipment where it is desirable to provide automatic protection to operating personnel. (*Ask for Data Sheet P108*).

B The MICRO SWITCH "EN" Series switches are capable of reliable, long-life performance under extreme environmental and mechanical conditions. They are completely sealed, cylindrical in shape and can be mounted wherever a through hole can be provided. Variations of the "EN" are capable of actuation by almost any means (see right hand column). (*Send for Data Sheet 105*).

C This is the first of a new series of "electrical memory" toggle switches being introduced by MICRO SWITCH. They offer a completely new concept in switching remotely controlled circuits. They promise to simplify basic circuit designs of radar units, computers, aircraft control panels and similar devices. The switch indicates through a pilot light or buzzer which circuit was last actuated. (*Send for Data Sheet 109*).

D MICRO SWITCH now offers a new series of low cost plastic encased switches especially designed for use on domestic appliances. In addition to their small size and high electrical capacity, these switches are ruggedly constructed for hard service. They are readily adaptable for use with auxiliary actuators. (*Send for Data Sheet 106*).

MICRO SWITCH *Engineering service is available at nearby branch offices. A call can save you time and money.*

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CONTROL ENGINEERS' BOOK NEWS *from McGraw-Hill*

Analysis and design techniques for treating random effects in control systems is the special subject of a new book. MIT's Laning and Battin give you practical help for securing optimum system design in their **RANDOM PROCESSES IN AUTOMATIC CONTROL.** The 429-page book covers each potential source of inaccuracy—shows how to determine its contribution to over-all system performance both systematically and quantitatively. $10.00*

Helping you gain a sound working knowledge of the mathematical techniques of analyzing dynamic forces in machines is DYNAMICS OF MACHINERY. By James B. Hartman, of Lehigh U., it shows how vector notation may be applied in extending two-dimensional kinematics and dynamics to three dimensions. **Its 429 pages include widely-used practices in designing automatic control systems and servomechanisms.** $7.50*

Why has much electronic equipment furnished to our ground forces proved unreliable in service—has even deteriorated in storage? This book, reflecting Rome Air Development Center studies, shows why—and outlined methods of overcoming the problem. All factors, including electrical, mechanical, environmental, and human, are considered. **RELIABILITY FACTORS FOR GROUND ELECTRONIC EQUIPMENT,** 280 pages. Editor-in-Chief, Keith Henney. $7.50*

A clear, basic book in industrial electronics is now available in an up-to-date second edition of Chute's ELECTRONICS IN INDUSTRY. Over 400 pages supply a complete, nontechnical description of industrial electronic circuits and equipment. Information on transistors, magnetic amplifiers, strain gages, tube characteristics, and circuit calculations is included—**also an introduction to servomechanisms and the field of automation.** $7.50*

How a typical large electronic calculator works and the problems it solves is made clear in **FASTER, FASTER,** 156 pages. By W. J. Eckert and Rebecca Jones of Columbia U., it deals with IBM's NORC—plainly discusses components, programming, maintenance, etc., of machines being widely used in business, science, and engineering. Indicates uses in factory and office automation programs. $3.75*

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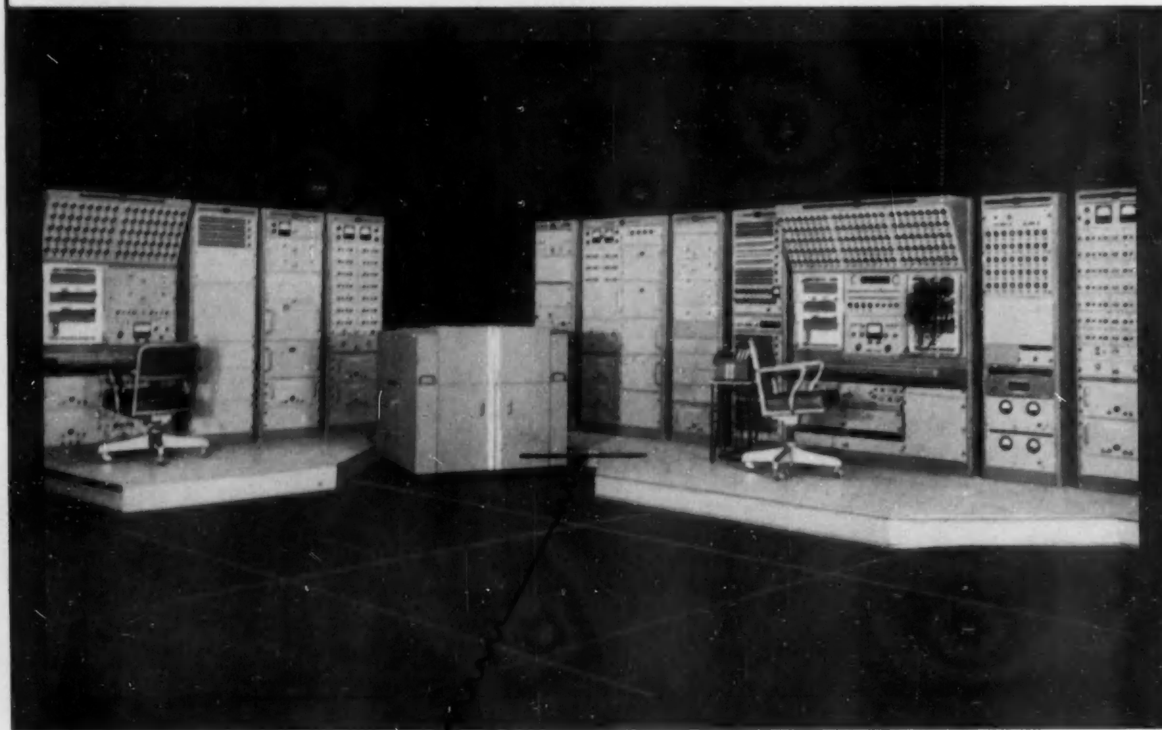

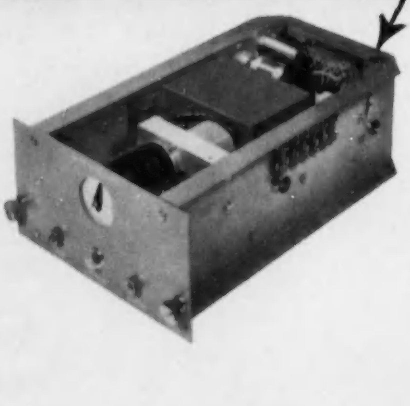

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PRECISION ANALOG COMPUTING EQUIPMENT

LONG BRANCH, NEW JERSEY

How Russia Updated Its Control Equipment

In a recent letter from Europe, engineer Mel Fusfeld gave his impressions of Soviet control engineers and their equipment. Once more—see April's *Pulse*, page 55—his comments are lively and perceptive. Below are some excerpts.

"In wandering over Europe I have accumulated scraps and chunks of information about the state of instrumentation and control in Russia. While the picture I get in total is far from definitive—this would require a more complete knowledge of the Russian economy on my part—it does represent a sketch of one sliver of their technology in which I have some background.

Vienna engineers saw the "evolution"

"Vienna is but a hop, skip, and a jump from the Iron Curtain, both in time and geography. But a few months ago this city and a substantial part of Austria were under Russian occupation. Hence most of the engineers I met in Vienna had worked under Russian direction; some were even Russian-trained.

"The Austrian engineers pointed out that in the field of control, just as in so many other fields, Russia undertook to close the tremendous technological gap which existed by outright copying. Foxboro valves, Taylor controllers, Fischer & Porter rotameters, for instance, all were manufactured in the U.S.S.R. on a carbon-copy basis.

"An eye-witness to this 'design' procedure describes it: 'when need for a new instrument arose, they would promptly procure a brand new catalog from each American firm in the field. A conference resulted in the selection of the most satisfactory unit for their needs. Then a designer-draftsman team would tear in and duplicate the instrument down to the last washer. Generally, no attempt was made to incorporate the better features of several instruments in one design.'

Down to the last washer

"Now some may remark that imitation is the sincerest form of flattery; that if you rely on copying you are always one step behind the fellow from whom you copy. Quite true. But the fact remains that this technique has enabled the Russians to duplicate the products of a quarter of a century of research and development in a handful of years. Indeed, their approach quickly brought them to the level where they could start worrying about the same problems plaguing their American counterparts.

"There was a time when Russian workmanship was 'just good enough'. But, at least in industrial instrumentation, this time

has passed. The workmanship in all the instruments which I saw was excellent. Surfaces were properly finished, wiring was neat, and the product was 'clean'.

"Regarding training, the Austrian engineers felt that Russian instrument men tended to go to extremes: either all theory and no practice, or vice versa. My instant reaction was that this is hardly confined to Russia. I have seen many a Western European engineer who wished to demonstrate a piece of equipment call on a technician to throw the switch.

All theory and no practice

"A few weeks later, in Milan to deliver a paper at the International Automation Congress, I had an opportunity to do some face-to-face talking with Russian engineers. As luck would have it, the Russian delegation was staying at my hotel. But they stuck fairly close together while dining and in the lobby—more because of a strange language and city, than for any other reason. I was determined to get into conversation with one of them somehow, and, finally (through a maneuver involving a baby monkey borrowed from a friend) I succeeded.

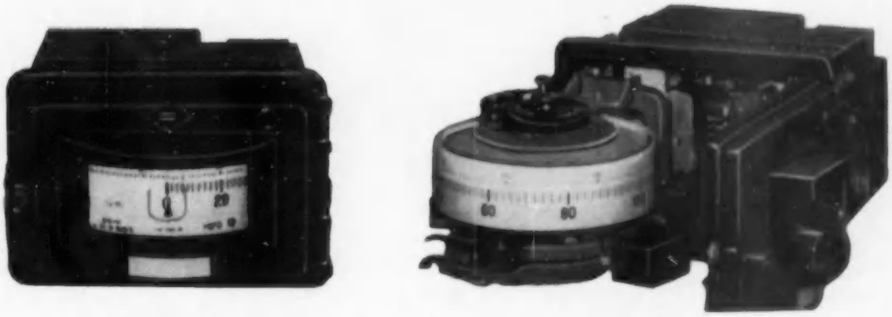
"My Russian friend Mike, as I shall call him, was an alert and thoroughly competent engineer in his late thirties, dressed like hundreds of other European engineers whom I had met. We sat down over the first of what were to be many cups of espresso. After first disposing of the standard international topics which always arise when two engineers get together: Italian automobiles (well formed) and Italian women (ditto), we got down to talking shop (we plan to publish Mel's impressions of this talk—the latter part, that is—in a future issue—Ed.).

A Philadelphia prototype

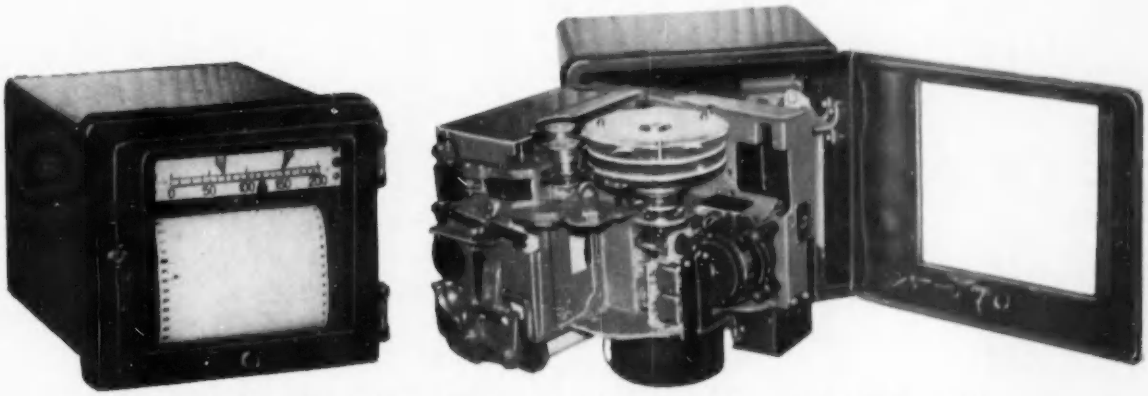
"A week later I visited the Russian exhibit at the Milan Fair and was fortunate enough to find about a half-dozen electronic recorders and controllers on view. The instruments were all basically L&N in design (even the new ¼-size recorder), but now with some important changes. The large recorder, for instance, used what appeared to be a Brown amplifier and chopper. Also, redesign had taken place, partly to suit the L&N design to Russian manufacturing techniques, partly to incorporate improvements. True, the larger recorder was still a one-second-for-full-scale-pen-movement, 0.5 percent error device, but it appeared good enough to compete on the American market."

Here's how one of the Russian exhibits looked at the Milan Fair. For a close-up, turn the page.

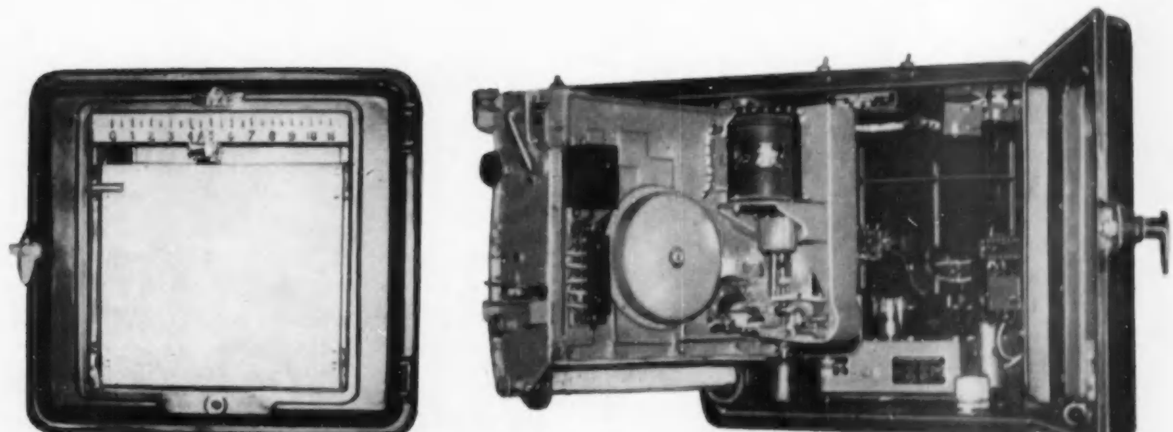
A quick view of the Russian electronic indicating and recording instruments at Milan indicated a striking resemblance to contemporary Leeds & Northrup designs. However, a close-up—particularly inside the case—proved that these were no mere carbon copies. Inside the case the similarity to L&N came through in small details such as the chart drive release and general heavy construction of the instrument castings.



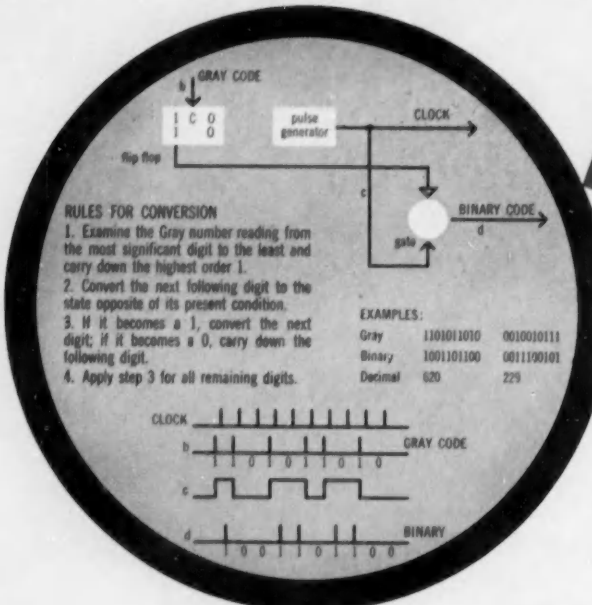
A Russian electronic indicating galvanometer-type pyrometer.



A compact recorder which bears striking resemblance to L&N's new ¼-size Speedomax H.



A full-sized electronic recorder that strongly suggests the L&N Speedomax G.



solving logical problems with Burroughs pulse control systems

converting Gray code to binary equivalents

Here is a simple method for converting Gray code to true binary equivalents. It was put into operation in minutes just by interconnecting Burroughs Pulse Control Units in accordance with the engineer's block diagram, without detailed specifications or complicated circuit designs. With pulse control equipment at his disposal, the engineer was able to turn immediately to other important problems awaiting his attention.

The majority of engineers solving logical problems are badly in need of such tools. Most are bogged down by equipment of limited use that must be redesigned and rebuilt for every new project . . . that clutters the path to a working solution instead of clearing and shortening it.

The smallest discrete units with which such a man can work are logical concepts . . . the basic logical operations. The ideal tools for him are these same operations, packaged for convenient and immediate use by simple interconnections—like the blocks in his block diagram. Such tools are Burroughs Pulse Control Units, which bring block diagrams to life in a matter of hours rather than weeks. Wherever logical problems are being solved with pulses they have earned the title "Tools For Engineers" by eliminating intermediate steps to a proof, obsoleting the frustrations and complexities of breadboarding.

Why not lift the burden of proof from your shoulders by passing pulse problems on to us? We'll gladly show you how Burroughs Pulse Control Units can bring your logical problems closer to a neat working solution . . . at no cost. Or, write for Bulletin 236.

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Control ENGINEERING
AUGUST 1956

Technical Meetings Must Improve

Technical meetings conducted by engineering societies serve to periodically communicate and establish a record. At these meetings engineers and scientists disclose their innovations in theory, technique, and product—and thus stake their claim as originators.

Past society meetings adequately served the engineer familiar with his field. But today's rapidly emerging new technologies, such as nuclear energy and automatic control, underscore the need for a function much more basic than an annual updating of what fellow engineers are doing. The control engineer, usually a "recruit" from a more venerable branch of engineering, seeks specifics, such as on the capabilities of available hardware. And by attending a meeting he also hopes to get an education in the engineering methods for integrating the hardware into complete systems without lengthy cut-and-try.

The great need for education in control has spawned meetings and conferences all over the world. A story on page 21 of this issue describes two: a seminar on automation for production engineers at Pennsylvania State University, and an international exhibit of measuring tools in London. News items in previous issues told of others: spring sessions in Milan (Italy), Cambridge (England), and Princeton University. And still the conclaves come: Engineers can go to Los Angeles this August for meetings on telemetering, computing, and electronic hardware. They can cross the Atlantic to Heidelberg (Germany) for rigorous sessions on the mathematics of control systems engineering. And they can top off the summer in New York in late September at ISA's International Meeting in the Coliseum.

Do these meetings give the control engineer the "how to" he needs? They are beginning to, but there can be vast improvements, such as:

- more clinics on specific types of equipment
- demonstrations accompanied by "chalktalks" on fundamentals, such as Ludeke's introductory session on nonlinear phenomena at the IRD (ASME) Princeton conference last March
- conferences based on papers distributed well in advance and involving discussion by small groups of engineers led by experts in the subjects

It is up to the control engineer who seeks basic and specific information to push for the improvements. The structure of the founding societies encourages such changes—but developing them is up to the membership.

THE EDITORS

1% accuracy, 0.1 mv to 300 v!

-hp- 400H High-Accuracy Vacuum Tube Voltmeter

New! 1% accuracy 50 cps to 500 KC
Frequency range 10 cps to 4 MC
10 megohm input resistance
12 ranges, 0.1 mv to 300 v
Direct readings in volts or db
Functions as stable amplifier

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-hp- 400D, highest quality, wide range, maximum usefulness. Covers 10 cps to 4 MC, 0.1 mv to 300 v. New amplifier circuit provides 56 db of feedback, (mid-range) for ultimate stability. 10 megohm input impedance prevents disturbing circuits. Sealed or long-life electrolytic condensers; rugged, trouble-free. $225.00

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New *-hp-* 400H Vacuum Tube Voltmeter combines broadest usefulness with wide voltage and frequency coverage, and the greatest accuracy ever offered in a multi-purpose voltmeter.

On line voltages of 103 to 127 v, accuracy is ± 1% full scale, 50 cps to 500 KC; ± 2%, 20 cps to 1 MC, ± 5%, 10 cps to 4 MC. Readings are direct in db or volts on 5″ mirror scale meter; 12 ranges cover 0.1 mv to 300 v. High 10 megohm input resistance minimizes loading to circuits under test. Stabilized amplifier-rectifier with feedback loop gives high long-term stability; line voltage changes as great as ± 10% cause negligible variation. Overvoltage protection is 600 v on all ranges. Highest quality, rugged construction throughout. $325.00.

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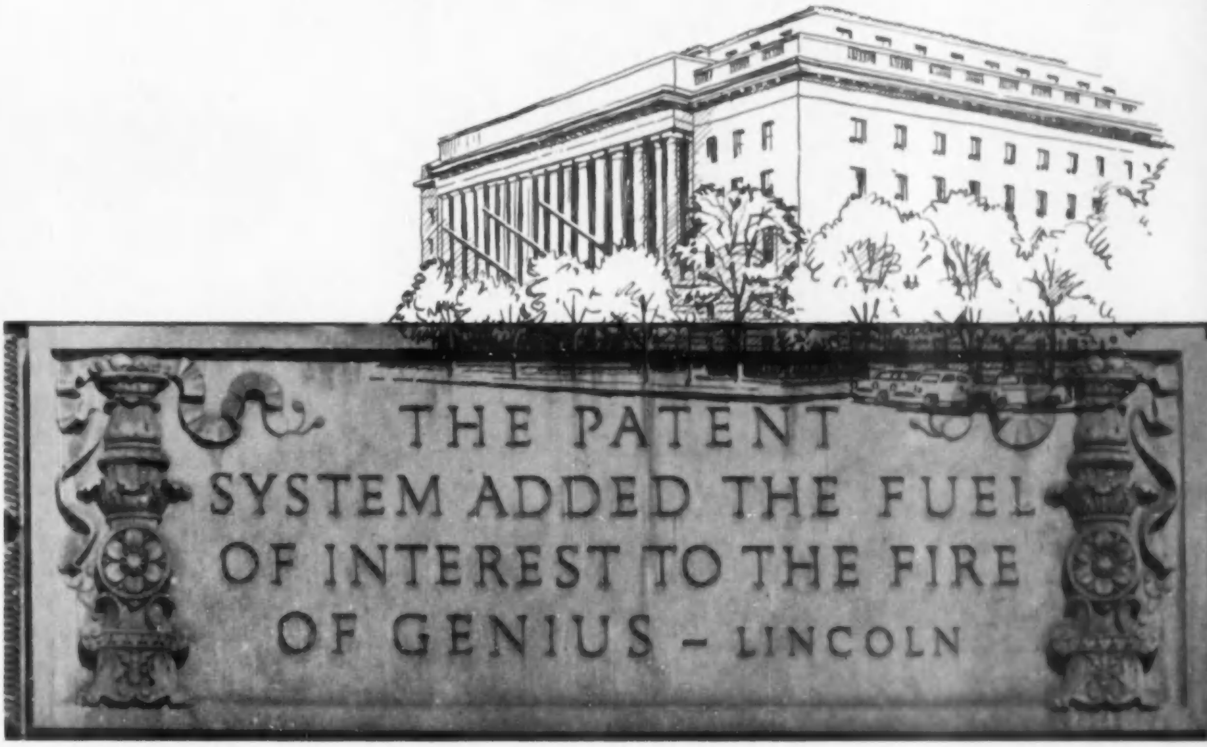


How Your Patent in Control is Processed

LLOYD E. SLATER, Control Engineering

On Washington's busy corner of NW 15th and E Streets sits a massive, columned edifice that acts like a huge computer in processing the ideas of our land. Spread throughout the seven stories of this Department of Commerce Building are the "blocks" of the computer: the "logic elements", or patent examiners; the "memory section", or 100,000-volume technical library and seven-million-copy foreign and domestic patent stacks where the examiners do research; the "input and output devices", or the hundreds of clerks, technicians, and scores of facilities that are used to expedite the flow of patents. Ten years ago this patent "computer" became overburdened by a sudden insurge of post-war inventions which doubled its backlog to

In 1955 the United States Patent Office received 78,480 applications from prospective inventors. Of these at least 3,600 were products or ideas for the automatic control loop—roughly 10 new control items per day. At the same time, the Office examiners staggered under a backlog of 221,872 pending applications. The inventor had to wait anywhere from six months to a year before an examiner even looked at his application. And then, if some of his claims passed muster—38 out of every 100 applications were completely rejected—he might wait three more years until the patent came to him.

Out of this welter of statistics rise some important questions from the control-field inventor. Why such delays? Is my invention being reviewed fairly in such a mass? And what is the Office doing to speed up the process? This article answers the questions about how your invention is processed by looking at—

1—How It Goes Through the Office
2—Who the People are Who Handle It
3—What the Processing Problems Are
4—How These Problems will be Solved

over 200,000 pending applications. The result has been a gradual lengthening of the time required to secure a patent and a growing distress among inventors—particularly knowledgeable control-field inventors—who question the "computer's" access time, its decision-making capabilities, and how up-to-date its equipment is.

There is only one way to answer the challengers: a visit to the Office to see its process, people, and problems.

1. How does it go through the Office?

A patent application usually starts with your idea in the hands of a skilled patent attorney and his visit to the Patent Office to use its vast public facilities to "search" your claims. But let us assume that your lawyer has made the search and is convinced that you "have something". He prepares the application, which includes your detailed drawings, the appropriate government fee (usually $30), and your oath of complete originality. What happens after this carefully prepared document is dropped into the corner mailbox?

Your thick brown envelope joins 14,000 pieces of mail, including roughly 300 other new patent applications, which reach the Office daily. The mail room extracts your fee and sends it to Finance, then routes your papers to the Application Branch where they are checked for formal compliance with patent laws (clearly set forth in a 91-page booklet which is available, for 25¢, from the U. S. Government Printing Office, Washington 25). The papers then go into a permanent folder, a number is assigned, and mechanized office routine creates an official receipt for you. The machines also click out duplicate index cards, one for the subsequent examiner and one for a file which will quickly locate your application at any stage in its handling. Meanwhile, all your drawings are examined for quality by the Drafting Branch and any assignments you have made are recorded by the Assignment Branch. Next photoprints of the drawings are made and all of your documents microfilmed. Your application finally is classified into one of the 67 Examining Divisions and is assigned to a specific examiner who is familiar with the technical area.

When your application gets to an examiner's desk it faces a wait of anywhere from six months to a year before he can look at it. But when he does reach it on his docket, it becomes his sole and dedicated preoccupation. He studies your complete application, then scans its claims and makes a tedious search through both past patents (U. S. and foreign) and literature for possible identical or similar inventions. If none exists your attorney may receive a letter, called an "Office Action", which happily advises that "all claims are allowed". This, however, is as rare as the dodo. More often the examiner may find that none of your claims defines an invention over the prior art and a much less happy letter goes to your attorney.

Usually, however, the examiner finds only some of your claims unpatentable and the letter to your attorney carefully details all the earlier patents and publications which prove this. If you accept these findings and file an amendment canceling the invalid claims, your patent will probably be issued immediately. But quite often your lawyer, after carefully studying the action, might suggest amendments that attempt to reclaim some of your original objectives. You must file these amendments no later than six months after any Office Action or your application is, by law, abandoned.

Your amended application goes back to the examiner, who again must place it in his docket and handle it in its regular turn, which may be a year later. Another search is usually necessary to verify your new claims. Once again a letter will go out, rejecting some elements of the amended application. If a compromise is not reached, this give-and-take can—and often does—go on over a few years until the examiner finds all of your claims allowable, or finally rejects your application.

Persistence Will Sometimes Out

Your attorney may visit the office at any time and try to persuade the examiner to change his mind, though he often has his own changed instead. However, when the examiner is adamant in his position, your lawyer, by paying a $25 fee, can request a hearing before the Board of Appeals—a "court" within the Patent Office.

The Board of Appeals is an interesting appellate body. It consists of the Commissioner of Patents, the Assistant Commissioners and nine Examiners-in-Chief, all appointed by the President and confirmed by the Senate. In addition the Commissioner may designate primary examiners or other persons of higher grade to serve as temporary acting board members for periods not exceeding six months. At the present time there are ten such acting members. The board sits in panels of three in deciding appeals and two three-man panels are on duty on hearing days—one skilled in chemical subjects, the other in mechanical and electrical technology. Panel make-up is constantly shuffled to secure a uniform action throughout the group. The record of the Board in cases appealed from its decisions to the courts is very good—only about 20 percent of its decisions so appealed are reversed by the higher courts. The volume of work received by the Board is very great and is on the increase. Because of its

THE PATENT OFFICE: *a look at its facilities*

Your attorney first "searches" the vast public archives of the Office.

Your application speeds into the system via tape-actuated machines.

Your claims are painstakingly studied by a patent examiner.

Your "final plea" at the Office may be before its Board of Appeals. Our camera caught an actual proceeding: General Electric Lawyer Donald M. Timbee (an Office "alumnus") argues before (l to r) J. E. Keely (an interference examiner); Leo P. McCann (a permanent Board member); C. A. LeRoy (a primary examiner).

Your patent, past all hurdles, gets the official seal of the Office.

Your patent, printed and with copies ready for sale, joins others passed that same week.

current backlog an applicant may have to wait as long as two years from the time he files his appeal until he obtains a decision.

If you have the finances, your persistent lawyer may appeal to still higher authority if the examiners' action is affirmed by the Board of Appeals. He may go before a special court in Washington, D. C., called the Court of Customs and Patent Appeals, or, finally, press your case in the United States Court of Appeals, District of Columbia Circuit. But, as indicated above, these higher courts rarely reverse a Patent Office decision. Actually, only one out of every 450 applications filed at the Office ever reaches these higher courts.

When your application has completely passed muster—through either regular examination or appellate procedure—your attorney will get a letter advising that it has been "passed for issue". A final fee of $30 must be paid within six months and then the patent will be printed and officially sealed, and you will receive a formal grant as its inventor.

While the patent processing routine described omits many of the special deviations that your application can take in the Office (i.e., it may become involved in an "interference" action with another, similar pending application or a patent) it does indicate how time can cascade in its processing. And it also hints at an elaborate organization, obviously well systematized, and staffed by painstaking, almost academic people.

By and large, then, it is the patent examiner who figures most strongly in this process. So let us now look at this individual—how well he is trained, where he comes from, and what his burdens are.

2. *Who are the people who handle it?*

Scattered in functional groups throughout the vast Commerce Building are the 800 men and women who form the Patent Examining Operation. The Operation's 67 different examining divisions—each oriented to a specific mechanical, electrical, or chemical art—are organized into seven examining groups, each under a supervisory examiner. Heading up each division, however, is a primary examiner who directs an average of eleven assistant examiners and is ultimately responsible for issuing the patent.

Your application may describe a new system for transmitting force in a hydraulic servomotor. Classification will reveal the technique fits into T. F. Murphy's Examining Group VI and can be specifically handled by R. H. Brauner's Div. 28, which specializes in hydraulics. Brauner will then assign it to one of his assistants, who will become its prime mover through the Office.

Invariably, the assistant examiner who handles your application will be a college graduate with a degree in engineering or applied science, or a BS with a major in chemistry or physics. Most of the assistant examiners also have law degrees, usually gained at a local university after joining the Office. The income of the examiner will vary with his experience. He starts with a GS-5 civil service rating at $4,480 a year and finds it possible to advance to GS-12 and $7,570 in five years. The average assistant examiner is an experienced man, around 40 years old, holding a GS-11 or GS-12 rating.

Examiner experience is the big factor in expediting your application. Consider the problem: the 800 examiners face information held in close to 3 million U.S. patents. Hence a skilled examiner should be familiar with the contents of 10,000 past patents—and, believe it or not, he usually is.

A recent survey made in the Office indicates how experience helps. It reveals that an average examiner does not reach full potential in work output until he has had eight years at the Office. A new man in his first year turns out only 31 percent as much as this veteran. Stated another way, salary advances included, it costs the Office $107 to dispose of a patent application using an inexperienced man as against $62 with an experienced examiner.

A personal tour of any examining division proves the quality of its people is high, their method of working objective and thorough. Almost all the examiners—particularly the older ones—seem to be fascinated with their job. They enjoy talking about odd cases, avidly review technical journals that bear on their field, are eager "to get at the next item". Their attitude toward their mission is revealing: "While I sympathize with the new inventor," one said, "my obligation is to protect the public and other inventors by finding the 'flaws' in his application."

Unfortunately, the valuable training and keen attitude of the patent examiner also make him a proper target for the outside lures of big salary and fast advancement. Turnover in the lower grades at the Office is high. In 1954, about 12 percent of the people in the valuable grades GS-11 and -12 left—many to become patent attorneys in industry.

But turnover is only one of several problems which plague the Office—and which delay the processing of your patent in control. Let us now consider some of these problems at more length.

HILLEL MARANS

Primary examiner Marans heads up Div. 42, which evaluates, among other things, signaling devices, indicators, and components of electronic computers. He got his engineering at Cooper Union, worked briefly as a draftsman on New York's Stuyvesant tunnel, then took a civil service exam and joined the Office during the first World War ("$1,500 was fine pay then"). His interest in control techniques was kindled right away: in '18 he studied the early system prototypes for submarine detection and fire control, later capped this off by following early patents in radar during World War II. He examined the first automatic stock market quotation board and centralized traffic control systems for railroads. Soft-spoken, dedicated, Marans will complete 38 years in the Office when he retires next Jan. 1.

EXCELLENZA L. MORSE

In 1950 Miss Morse (who really is Mrs. G. N. Westby, the wife of another Office examiner) became the first woman primary examiner. "But I'm not unique," she says. "There are 25 other women examiners who will surely fill posts like mine in time." Excellenza studied physics at MIT and got her Master's in 1923. After joining the Office in '25 she went on to a law degree at nearby George Washington U. Her technical forté has been "25 years of specialization on electromagnetic circuit breakers", although she will admit that this also has taken in many aspects of programmed and automatic machine control. In 1953 she was moved over as chief of Div. 61, which includes time controlling techniques. Modest and friendly Miss Morse is quick to applaud others.

ROBERT A. O'LEARY

Armed with a fresh chemical engineering degree, Bob O'Leary joined the Office right from Catholic U. in 1925. He immediately started law at Georgetown, getting his degree in '30. Like many other examiners, he is a member of the D. C. Bar and may practice before the Supreme Court. Articulate Bob shows a keen legal mind as well as practical interest in his field. Regarding control techniques: "The control system in the application cannot be a mere idea for a desired result—it must be shown applied." As for basic patents: "Many are years ahead of their time, but expire before commercial use." In 1949 Bob was appointed chief of a division and is now head of Div. 30 which covers the vast technical waterfront of "temperature and humidity regulation".

3. What are the problems?

From the prospective inventor's standpoint, the obvious problem at the Patent Office is the huge backlog, which usually anchors his application for an average of three-and-one-half years—in 1955 this backlog reached an all-time high of 221,872 pending applications. In reviewing the people who do the work, we saw how valuable experience is to the examiner in moving this backlog. And how turnover among experienced personnel creates a problem of constantly staffing with less productive people at the Office.

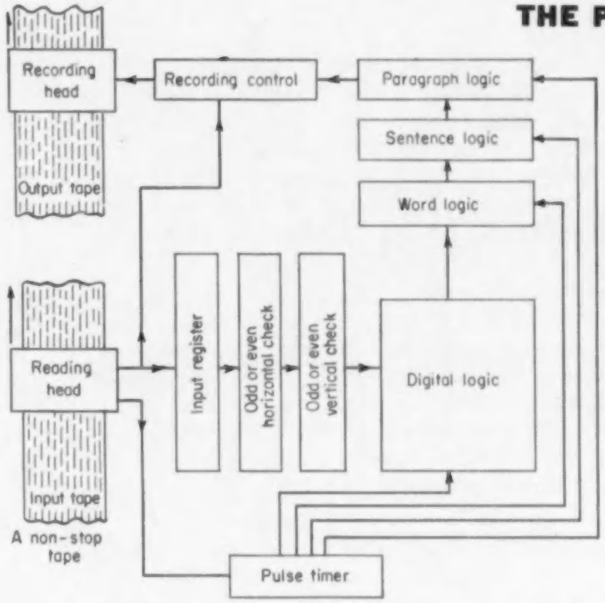
From the direct workload standpoint, then, the problem boils down to the number and quality of people on hand to process your patent—a problem that can only be solved at a Federal level in the forms of new salary structures, better working facilities, and more appropriations for the Office.

From the backlog standpoint, however, the problem is compounded by increasing complexity in the patent art itself. Each year a growing number of patent applications are filed, and all are somehow based on technical background reposing in over 2.7 million existing U.S. patents. The job of searching this prior art is thus a pyramiding time-consumer. The Office has systematized its approach to the search with a Classification Div., which has placed all past patents into 307 main classes and over 50,000 subclasses. This indexing system helps the examiner "find" prior art. However each year it becomes more necessary to create relatively smaller and more clearly defined patent groups to eliminate redundancy and blind alleys in the search.

The table below offers some of the results of a survey conducted among examiners who handle control-field products and gives an idea of the frequency of applications in our field alone and some of the technical problems these applications create. Also included are estimates of the trend to corporate "sponsorship" of patents and the frequency of completely unique inventions.

THE PATENT OFFICE: *a look at control product problems*

PRODUCT	NO. PER MONTH	AS MANY 5 YRS. AGO?	RATIO BETWEEN CORP. vs. SELF-ASSIGNED	HOW OFTEN A REAL INNOVATION	SPECIAL PROBLEMS IN HANDLING
AUTOMATIC PILOTS	5	yes	10:1	rarely	applicants should study past patents: they often duplicate progress
AUTO. WEIGHING SCALES	8	yes	3:2	every 6 months	be clear: both the applications and references are unusually complicated
CALCULATORS & COUNTERS	35	no	4:1	1 a yr. at most	these applications are highly complex; very few skilled people to handle them
ELECTRIC METERS	6	yes	1.3:1	once in 20 years	these systems often are hidden as parts of more involved and complicated systems
MASS SPECTROMETERS	2	yes	15:2	rarely	a narrow field: study past patents carefully before making application
MEAS. & TEST INSTRUMENTS	70	no	1:1	once in 2 years	need broad viewpoint: closely related to all other arts, require broad search
METAL-MACHINING ITEMS	15	yes	9:1	once in 15 yrs.	complex diagrams involve electric, hydraulic circuitry, yet no correlation
MOTOR-CONTROL SYSTEMS	5	same	4:1	once in 30 yrs.	trend to fluid pressure and electronics complicates link to earlier inventions
SELF-PROP. FLUID SYSTEMS	5	no	7:3	once in 12 yrs.	diagrams usually poor: need more liberal use of arrows, legends to show flow
SIGNALS & INDICATORS	36	no	7:3	once in 12 yrs.	electronic computer components make this group complex and extremely lively
TEMP. & HUMID. CONTROL	10	yes	4:1	steady progress	an extremely wide search needed because of the broad claims usually made
TIME-CONTROL APPARATUS	4.1	no	7:3	rarely	novelty searches are of broad scope, involve many arts, and thus difficult



D. D. Andrews, Chief of the Classification Group, and an early block-diagram concept of mechanized search system.

4. How will they be solved?

Today the Patent Office, under Commissioner Robert C. Watson, is deep into a dynamic program to solve its glaring problem of backlog and its hidden problem of creeping technical paralysis.

The direct attack on backlog involves a massive addition of manpower to slash the pile of pending applications to 100,000 by 1965. More than 200 new examiners have been hired since June of '55, and the Office plans to recruit several hundred more by 1958 to build a complete roster of about 1,050 examiners.

Last October Watson developed for official review an extremely clear and well-documented report on Patent Office needs. Assuming that Congress "buys" his program, the near future should see a general upgrading in Office salary structure and better job opportunities to line it up more happily with outside industry. These new facilities are also possible: a testing and demonstration laboratory; training equipment and space; better arrangements for visitors; a permanent exhibition hall.

However, the most fascinating—and to a control engineer, most promising—problem solving program at the office has to do with the application of modern data processing techniques to "mechanize the search".

In 1950 a preliminary study suggested that patent classification might be amenable to digital handling. A committee was set up under Dr. Vannevar Bush in 1954 to examine the idea and report its findings to the Secretary of Commerce. In late 1954 the Office, in cooperation with Bureau of Standards, launched its mechanized search project based on this committee's recommendations. In 1955 six men under D. D. Andrews, Classification Chief, and B. E. Lanham began the actual work. A year later, Andrews was able to report a real start in digitally classifying 151,000 chemical patents and the formation of a Research and Development unit at the Office ("for the first time in its history") which he now heads.

Essentially, the mechanized search involves converting all classified past patent information into a code that can be fed into and read from a memory system by high speed computer techniques. The code-classifying job is an epic one. Andrews has now assigned men to such advanced "basic" studies as the development of nonredundant "ruly english" (borrowing heavily from communications theory) and the use of Boolean algebra to expedite command coding. At the same time, Bureau of Standards reseachers are busy testing experimental command codes on SEAC in a study to determine the parameters for a functional data processing system.

In May, Andrews proudly announced "An achievement! We have completely encoded a patent in all detail and it is now possible to mechanically retrieve any item of information in it in response to a search." The historical patent: a gin (liquor) which bears medicinal extracts.

We'll drink a toast (in gin, of course) to the future of this project.

Here's a Way to Measure Pneumatic Component Dynamics

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Wilmington, Del.

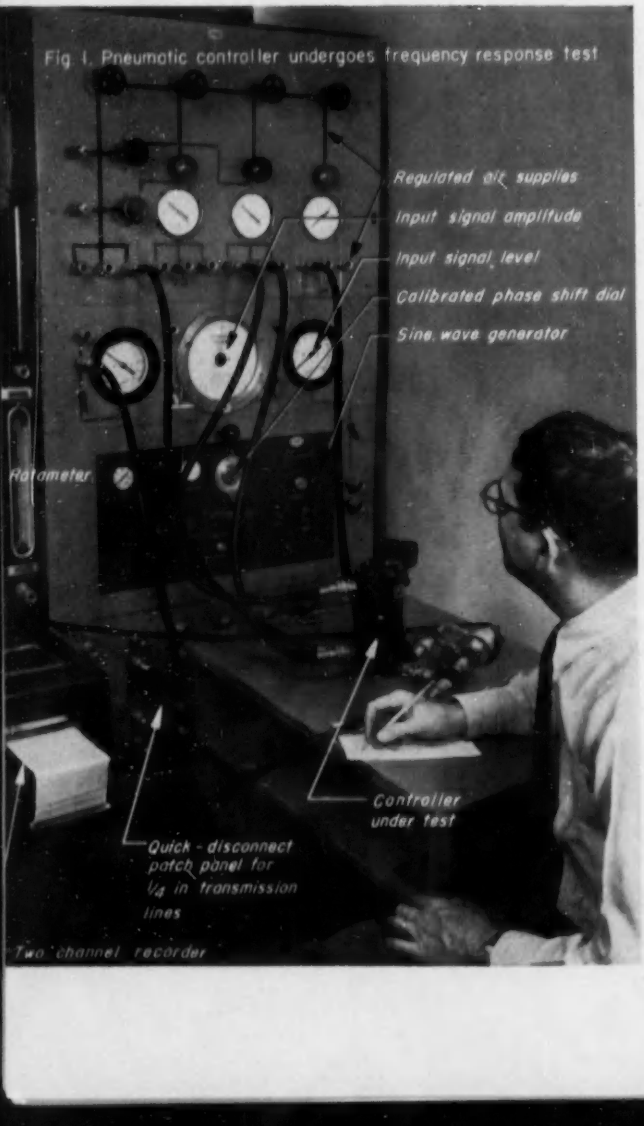


Fig. 1. Pneumatic controller undergoes frequency response test

Although process industries have used pneumatic control systems for many years, until recent years the dynamic properties of these systems caused little concern. But the current trends toward chemical reactions at high pressures and toward the rapid and continuous movement of fluids from one operation to another within the processes now direct the attention of process and control engineers to the dynamics of all components in process control systems. Even in batch processes, some of them inherently slow, the press toward quantitative control system design has made imperative a detailed knowledge of the dynamic properties of the control components. Because much of the data is unavailable from manufacturers of this equipment, users have had to obtain it independently. Here is how.

TEST EQUIPMENT

Frequency-response curves, in which magnitude ratio and phase-shift are plotted against frequency, can describe the dynamics of the pneumatic components. Figure 1 illustrates a test panel used in determining frequency response. It includes two sources of variable-frequency pneumatic signals:

▶ Mark I generator (Minneapolis-Honeywell)[2]: supplies both electric and pneumatic sine waves ranging from 0.0005 cps to 7 cps (see Fig. 2A).

▶ Mark II generator: A Hewlett-Packard low-frequency oscillator provides an electric signal varying from 0.01 cps to 1,200 cps. The oscillator drives a Taylor electric-to-pneumatic converter to develop a pneumatic signal from 0.01 cps to 50 cps (see Fig. 2B) for schematic of generator.

THE GIST: Many engineering factors determine why you select a specific component for an automatic control system—reliability, cost, maintenance, manufacturer service, to name a few. But in recent years one controversial and little-understood factor has assumed more and more importance in the selection: the factor of product dynamic performance.

This article, and two which will follow, explain how the dynamics of pneumatic instruments are determined at du Pont's Engineering Research Laboratory. Data of this nature, the author holds, are essential not only in evaluating the dynamic performance of components, but also in predicting the dynamic performance of *planned* control systems which may consist of many components and their interconnecting pneumatic transmission lines. And if the control engineer needs to know the dynamic performance of a specific existing system, he can use these data to piece together the system's overall response from transmitter to control valve.

The group of articles describes:

(1) Comprehensive procedures for testing dynamic characteristics of pneumatic controllers

(2) How to derive, and measure the parameters of, the transfer functions of pneumatic controllers

(3) Collected data on the dynamics of controllers, transmitters, transmission lines, valve actuators, positioners, and boosters

Figure 2 illustrates the frequency response measurement setup for the two combinations. Data reduction with the Mark I generator makes use of a calibrated phase-shift dial that the operator rotates to match the phase shift of the tested component. Reference Lissajous patterns on the oscilloscope give an extremely accurate indication of match, even in the presence of considerable signal distortion. With the second combination, magnitude ratio and phase data are read from the recordings made by a Sanborn Model 60-1300 two-channel recorder.

Sinusoidal signals are not used exclusively. Step disturbances can measure controller proportional band by the procedure given in C-2 and controller reset by the procedure given in D-2.

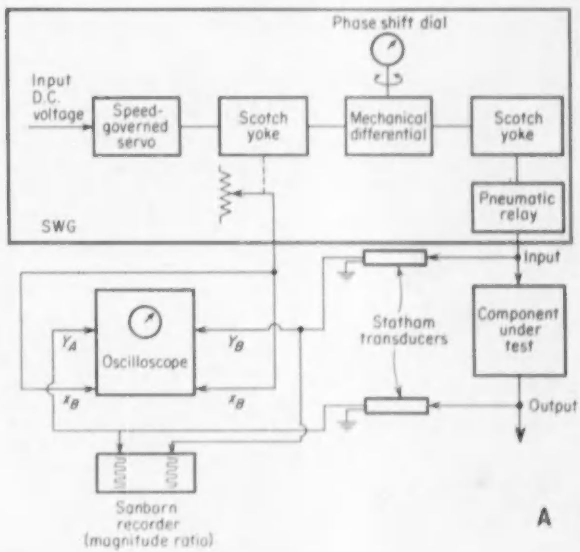
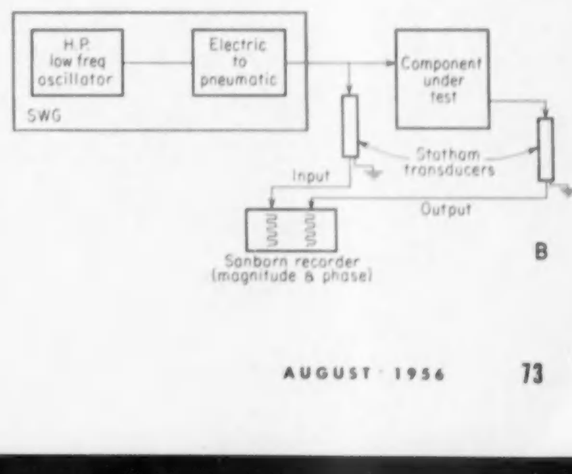


FIG. 2. Schematics of pneumatic test setups.

A. MK.I Sine Wave Generator. Signal Y_B from the input pressure transducer is connected to the oscilloscope's vertical plates and the reference signal X_B to the horizontal plates. They produce an elliptical Lissajous pattern on the oscilloscope face. Adjustment of the phase dial to close the Lissajous pattern to a line brings the two signals into phase match. The dial reading is recorded. In the same way the phase of signal Y_A from the output pressure transducer is compared with the phase of reference signal X_B, the dial rotated until they match, and the new dial reading recorded. With due regard to sign, the phase shift through the component under test is the difference between the two readings.

B. MK.II Sine Wave Generator. Magnitude ratio and phase shift of the tested component are measured on the recording.



CONDITIONS OF TEST

Conditions must be set up so that they will yield representative and reproducible test results. Based on studies of test conditions, recommendations are:

1. Signal level: 9 psig at the output of transmitters and controllers with spot checks at 6 and 12 psig.
2. Signal amplitude: Sine wave of plus and minus 0.5 psi amplitude output of controllers and input to transmission lines.

The pneumatic output signal *amplitudes* of transmitters and controllers must stay constant at all frequencies during the test to maintain the output dynamic resistance of the component. The input to the controller or transmitter is usually of high enough pneumatic impedance so that the input circuit absorbs a minimum of energy. Hence, variations in input signal amplitude have little or no effect on the frequency bandwidth of the instrument when the amplitude is between plus or minus 0.1 to 2.0 psi. But because the output pressure and flow follow curves such as those shown in Figure 3, it is evident that the average output dynamic resistance varies with changes in the output pressure amplitude. Figure 3 illustrates typical output pressure-flow curves for controllers (curve 1) and unpiloted transmitters (curve 2).

The pressure-flow curves have this practical significance:

▶ They represent the maximum flow the component can pass for a given signal change.

▶ They may be nonsymmetrical, as is the one (curve 2) for the unpiloted transmitter. This is quite important when long transmission lines connect the transmitter to the controller. For then the transmitter and its load rectify oscillating signals, e. g., for pulsating flow. Consequently the controller will receive a signal offset by an amount proportional to the pulsation frequency.

Discussion

The test procedures given were set up for the pneumatic controller. They are specialized in that they are concerned with determining the controller characteristics and with those conditions which affect controller performance. By measuring the input and output signals right at the controller, the connected transmission lines can be treated as loads on the controller. Because the loading effects are thus included, the resulting controller frequency response curves may be added graphically to transmission-line frequency-response curves measured in the same way. Data on pneumatic transmission lines are available from several sources[2, 3], but they should be used with caution because different authors may not use similar test conditions. The third article in this group will include experimental data on pneumatic transmission lines.

During the course of this work pneumatic differential pressure transmitters were tested with air as the signal fluid. The resulting dynamic data pertained only to the instrument and its transmitting pneumatic relay. When differential pressure transmitters are used in liquid service, the dynamics of the manifold from the pipe-line flow orifice to the instrument are not negligible, especially when the flow pulsates. Furthermore, those dynamics depend upon the physical dimensions of the manifold and the physical properties of the process fluid. Because it is not possible to include all the manifold configurations and all the process fluids, the author recommends standardization of transmitter testing with air as the process fluid.

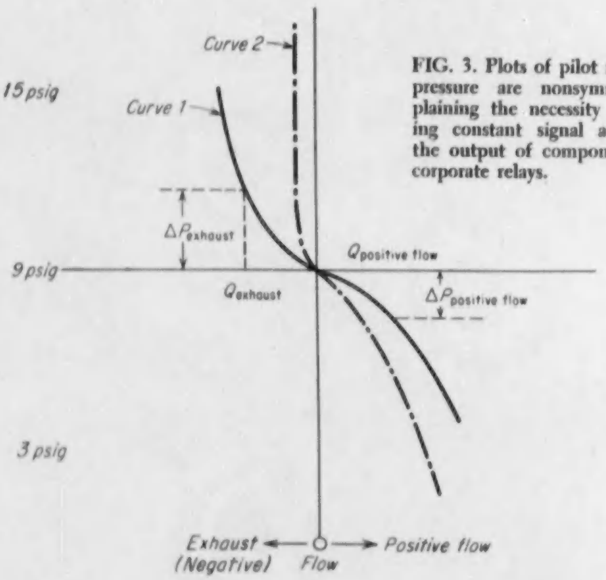


FIG. 3. Plots of pilot relay flow-vs.-pressure are nonsymmetrical, explaining the necessity of maintaining constant signal amplitudes at the output of components that incorporate relays.

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2. *PNEUMATIC TRANSMISSION LINES*, J. C. Moise, ISA Paper No. 53-10-4.
3. *ATTENUATION OF OSCILLATORY PRESSURES IN INSTRUMENT LINES*, A. S. Iberall, Journal of Research of the NBS, Research Paper RP2115-U-45, July 1950, p. 85-108.
4. *VALVE ACTUATORS TIE PRECISION TO POWER*, C. D. Close, CONTROL ENGINEERING, p. 97-104, Vol. 2, No. 9.

PROCEDURE FOR PNEUMATIC CONTROLLERS

This section reproduces in full the test procedure for evaluating the dynamics of controllers. Sections in the third article will describe test modifications for transmitters and valve actuators. The author hopes that the sections will guide ultimate standardization of such testing procedures in industry.

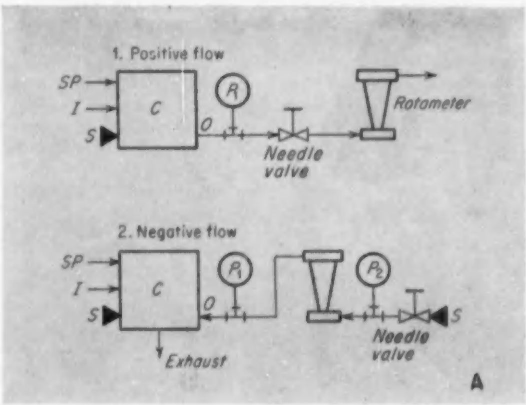
SYMBOLS

C	Controller
DPT	Differential pressure transducer
I	Input Signal Pressure
O	Output Signal Pressure
I	Input Signal Pressure
I_{pp}	Peak-to-Peak Sine Wave Input Signal
O_{pp}	Peak-to-Peak Sine Wave Output Signal
PB	Proportional Band
SP	Set-Point (reference)
S▶	Supply
SWG	Sine-Wave Generator (Pneumatic)

NOTES

1. For the frequency response tests, the alternating pneumatic signal is 1 psi peak-to-peak about a nominal value of 9 psig, unless otherwise specified.
2. Output terminates in three ft of ¼ in. tubing connected to a 1.5-cu-in. volume unless noted otherwise.
3. Statham differential pressure transducers with required backup pressures and a full-scale range of plus or minus 0.5 psi or 2.0 psi are used for all pressure measurements.
4. When controller is not tested open-loop, feedback path is through a 300-to-500-cu-in. tank and a 0.0145-in. orifice (see D-1).
5. When procedure calls for setting reset at maximum, this refers to a reset dial calibrated in minutes per repeat. Set at minimum if calibrated in repeats per minute

A. Evaluation of Controller's Pilot Relay Output Resistance To Air Flow:



Two conditions to be investigated are:

a. Air flow from the controller to its load (transmission line and/or valve). Called positive flow.

b. Air flow from the load through the relay to the atmosphere. Called negative flow.

1. Measurement Setup For Positive Flow (See Schematic A-1 directly to the left):

a. Set the reset at maximum minutes per repeat, rate (derivative) at minimum minutes, and PB at 100%.

b. Set SP, I, and O at the same nominal level (9 psig) with the needle valve closed. Set O by adjusting zero of controller.

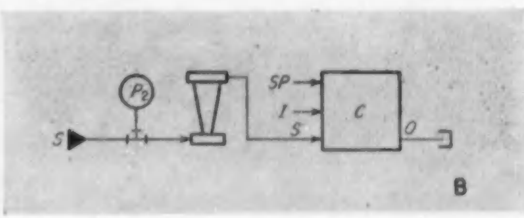
c. Incremently open needle valve, decreasing P_1 from nominal level in b. Plot flow through rotameter vs. pressure P_1 as in Figure 3. If rotameter is calibrated at atmospheric pressure compensate for P_1.

d. Repeat steps a through c inclusive at nominal levels of 6 and 12 psig and plot positive flow vs. P_1 on graph described in step c.

2. Measurement Setup for Exhaust (Negative) Flow (See Schematic A-2):

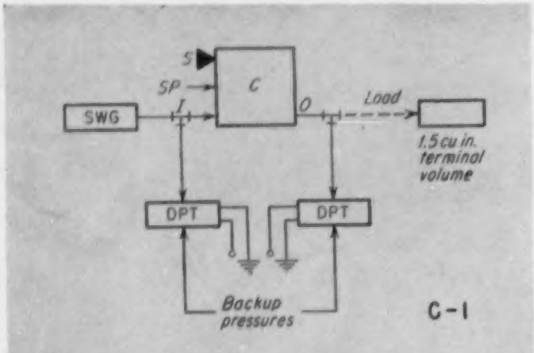
a. Repeat steps a and b above. Increase P_1 by opening needle valve in incremental steps. Plot flow through rotameter as exhaust (negative) flow on Figure 3 vs. pressure P_1. Repeat at nominal levels of 6 and 12 psig.

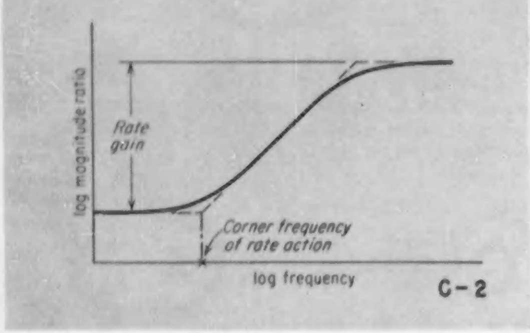
B. Evaluation of Controller's Nozzle and Relay Static Air-Consumption



1. Adjust SP, I, and O for 9 psig.
2. Adjust controller settings as in A-1a.
3. The rotameter reading is the static air consumption.

C. Calibration of Proportional Band and Rate (Derivative) Dial Settings





1. PB CALIBRATION: The frequency-response method is used to determine the cutoff frequency of the controller at various PB settings and for calibration. Schematic C-1 shows measurement setup.

a. Adjust pressures as in B-1. Set reset at maximum (See item 5 in Notes.) Set rate at minimum minutes.

b. Run a frequency response test from 0.1 cps to 10 cps for 3 PB settings at, above, and below 100%. Do this for loads of 3, 50, and 200 ft × ¼ in. copper tubing terminated with a 1.5 cu-in. volume.

c. Vary the frequency of the input signal and maintain the output amplitude (0_{ac}) constant. Record I_{ac} and 0_{ac} (both peak-to-peak values) as functions of frequency. Measure phase shift from recorder chart. Plot log of magnitude ratio $\left(\frac{O_{ac}}{I_{ac}}\right)$ and phase shift vs. log of frequency for each tube length.

d. Repeat steps C-1b and C-1c for SP, I and 0 set at 6 and 12 psig. Spot check several points on the magnitude ratio and phase curves to determine the effects of pressure level.

2. Step-Response Method Used For PB Dial Calibration (as an alternate method to C-1): Schematic C-1 shows measurement setup except that I is held at 9 psig.

a. Set dials and pressures as in C-1a.

b. Apply a step pressure change (ΔSP) of 1.0 psi at SP.

c. Record the pressure change $\Delta 0$ at the output.

d. The actual PB setting is computed from the following equation:

$$\%\ PB = \left(\frac{\Delta SP}{\Delta 0}\right) \times 100$$

e. Repeat C-2a to C-2d for several PB dial settings. Plot PB dial settings vs. actual PB obtained in Step C-2d.

3. Calibration of Rate (Derivative) Setting: Schematic C-1 shows measurement setup.

a. Set reset at maximum (see items 5 in Notes.) Set PB dial at 200%.

b. Adjust the pressures as in B-1. Set rate at 0.1 min.

c. Run a frequency response test from 0.01 cps to 10 cps. Record I_{ac} and O_{ac} as functions of frequency. Measure phase from recorder chart.

d. Plot log magnitude-ratio and phase-shift versus log frequency as in Figure C-2. The actual rate setting (τ_d) is computed from that frequency (f_d) at which the magnitude ratio is 1.41 according to the equation

$$\text{actual } \tau_d = \frac{0.159}{f_d \times 60},$$

where f_d is in cps and τ_d is in minutes.

e. Repeat the above for several rate dial settings, including extremes, and plot a curve of rate dial setting vs. the actual rate as computed in C-3d.

f. If interested in rate gain it can be measured from Figure C-2.

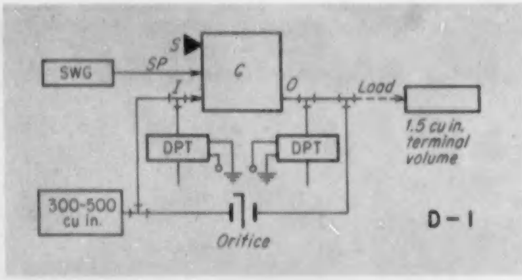
4. Evaluate Interaction (if any) Between PB and Rate Dial Setting. Schematic C-1 shows measurement-setup. Experience indicates that in practice the effective interaction is negligible but here is a method of evaluation:

a. Set pressures as in B-1. Set reset at maximum (See items 5 in Notes.) Set PB dial at 100% and rate dial at 0.1 min.

b. Adjust test-signal frequency for a controller magnitude-ratio $\left(\frac{O_{ac}}{I_{ac}}\right)$ of 1.4. Record frequency f_o necessary.

c. Change PB to 50% and then to 200%. Readjust test signal frequency to f_1 to maintain (1.4) X 2 magnitude ratio for 50% PB and to f_2 to maintain $\frac{1.4}{2}$ magnitude ratio for 200% PB; f adjustment is interaction.

D. Calibration Of Reset Dial Setting



1. Frequency Response Method: Schematic D-1 shows measurement setup.

a. Set pressures as in B-1 with rate set at minimum minutes and PB at 100%. Set reset dial at 0.1 min per repeat or 10 repeats per minute.

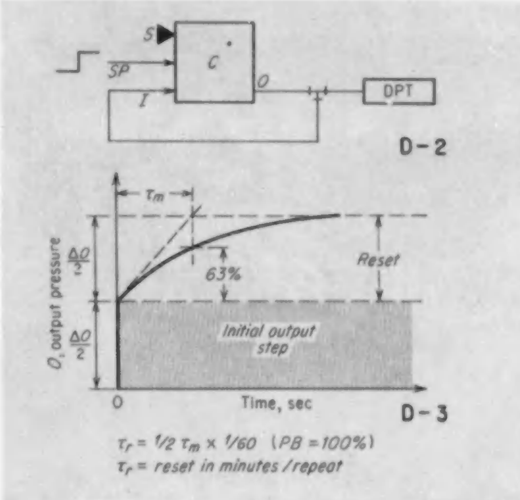
b. Run a frequency response test from the lowest frequency available (about 0.001 cps) to 1 cps. Record I_{ac} and 0_{ac} as functions of frequency. Measure phase shift from recorder chart.

c. Plot log magnitude ratio and phase vs. log frequency. The actual reset setting (τ_r) is determined from the frequency (f_r) at which the magnitude ratio is 1.41 according to the equation

$$\text{actual } \tau_r = \frac{0.159}{f_r \times 60}$$

where f_r is in cps and τ_r is in minutes.

d. Repeat above for several values of reset settings and



plot the reset dial setting versus the actual reset setting as computed in D-1c.

2. Step Response Method (alternate to D-1): Schematic D-2 shows measurement setup.

a. Set dials and pressures as in D-1a.

b. Set PB at exactly 100% as follows:

Apply a 1 psi step change in pressure at SP; adjust the PB dial until one-half of the output change on the recorder is reset action (see Figure D-3). Actual PB value will now be 100%.

c. Shift the zero on the recorder so that the reset action occupies most of the chart.

d. Apply a step change in pressure ($\Delta SP = 1$ psi) and compute the actual reset setting from the following equation:

$$\text{actual } \tau_r = \frac{\tau_m}{120}$$

where τ_m is the time in seconds measured to the 63 percent point on the transient curve.

e. Repeat D-2a to D-2d for several reset-dial settings and plot the reset-dial setting versus the actual reset setting as computed in D-2d.

E. Evaluation of Interaction (if Any) Between PB and Reset Dial Setting:

1. Frequency Response Method: Schematic D-1 shows measurement setup.

a. Set dials and pressures as in D-1a.

b. Repeat steps b and c of C-4. Calculate:

$$\% \text{ interaction} = \frac{f_1 - f_o}{f_o} \times 100 \text{ and } \frac{f_o - f_2}{f_o} \times 100$$

2. Step Response Method: See schematic D-2 for setup.

a. Set dials and pressures as in D-1a.

b. Repeat the procedure of D-2b in order to set PB exactly at 50 per cent, by adjusting the PB dial until one-third of the output pressure change is reset action; then repeat D-2b in order to precisely adjust PB to 200 per cent by adjusting the PB dial until two-thirds of the output pressure change is reset action.

c. The actual reset setting is calculated from the following equations:

$$\text{actual } \tau_r = \frac{2/3\,\tau_m}{60} \quad (PB = 50\%),$$

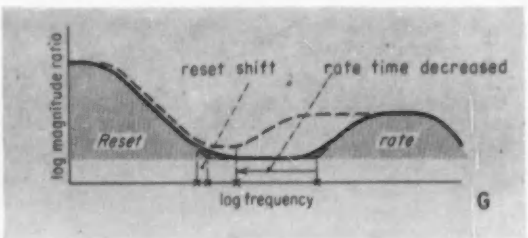
$$\text{actual } \tau_r = \frac{1/3\,\tau_m}{60} \quad (PB = 200\%)$$

where τ_m is measured in seconds, τ_r in minutes.

F. Step or Frequency Response Method—Which to Use

Frequency response tests determine both the corner frequency and the shape of the reset action as a function of frequency. However, in all controllers tested, the observed shape follows a rising slope of 6 db per octave with decreasing frequency within the limits of the reset gain. Hence, in the interest of saving time, the step upset method is recommended for checking reset-dial settings. The reset corner frequency (see Figure G) equals $1/120\ \pi\tau_r$. A standard template (such as the one made by Harvard Cooperative Society) for an integrator then gives the shape of the frequency response plot.

G. Interaction Between Rate and Reset—Is It Worth Worrying About?



The solid line in Figure G shows the simplified magnitude ratio of a proportional-plus-reset-plus-rate pneumatic controller. From the corner frequencies one can determine the rate and reset times. They are functions only of the rate- and reset-circuit dynamics. Therefore the question of whether rate and reset interact is answered by adjusting the dynamics of one and determining whether it affects the dynamics of the other. Broken lines in the figure show the reset corner shift caused by a decrease in the rate time. Although the shift is slight, it is interaction. However, actual tests indicate that it normally is less than 5% of the reset setting, and therefore hardly worth considering.

Note also that the magnitude-ratio curve picks up between the rate and reset corners when they approach one another. This is not interaction. Nor is it evidence of a change in proportional band. It is nothing more than a natural and predictable effect.

1. Test for Rate and Reset Interaction: Schematic C-1 shows the measurement setup.

a. Set PB at 100% and set pressures as in B-1.

b. Pick as low a value of reset as drift stability of the controller allows without feedback. (Drift is important only inasmuch as the output signal might drift during several cycles at the test frequency).

c. Adjust rate setting according to this expression:

$$\tau_d = \frac{\text{rate gain}}{5.0} \times \tau_r$$

d. Run frequency-response test from 0.001 cps to 10 cps.

e. Compare the measured frequency response curve with that constructed from the following expressions in the vicinity of the corner frequencies.

$$\text{Magnitude ratio} \left(\frac{O_\omega}{I_\omega}\right) = \frac{\sqrt{(\tau_r^2\omega^2 + 1)(\tau_d^2\omega^2 + 1)}}{\tau_r\omega};$$

phase shift $= -90 + \arctan \tau_d\omega + \arctan \tau_r\omega$, where $\omega = 2\pi f$ and f is in cycles/sec.

f. The deviation at the corner frequencies between the constructed and actual curves is a measure of this interaction where τ_r and τ_d are actual settings.

Use Taps to Compensate Pot Loading Errors

JACK GILBERT, Norden-Ketay Corp., Norden Laboratories Div.

THE GIST: When a linear potentiometer is resistance loaded, the output voltage is no longer a linear function of shaft position. In "Here's a Short-cut in Compensating Pot Loading Errors", CONTROL ENGINEERING, February 1955, the author described a graphical method for locating one tap and determining shunt resistor value to reduce loading error by a factor ranging from 6 to 9, Figure 1. But if this reduced error still cannot be tolerated, it is necessary to buy a load-compensated function pot or to consider using more taps. Winding compensation is unsatisfactory, though, since loading errors are still in excess of single-turn potentiometer resolution for load ratios below 20 to 1, and, in any event, the cost, delivery, and design inflexibility of a function pot make it less attractive than a linear pot with taps and shunting resistors.

Thus, the problem is to reproduce the desired function with a linear pot, using a minimum number of taps and resistors consistent with the allowable error. The following procedure limits loading error to the best resolution of a single-turn pot. Then, with a resolution of 0.025 percent, the maximum permissible loading error is about (0.5 percent/load ratio) for a load ratio of 20. Four, two, and five tap pots are considered.

NOMENCLATURE

- a = load resistance or load ratio (ratio of load resistance to potentiometer resistance)
- R_1 = compensating resistor
- X_o = tap location of compensating resistor
- X = wiper location
- R = potentiometer resistance (normalized to 1)
- e = input voltage to potentiometer circuit
- e_o = output voltage

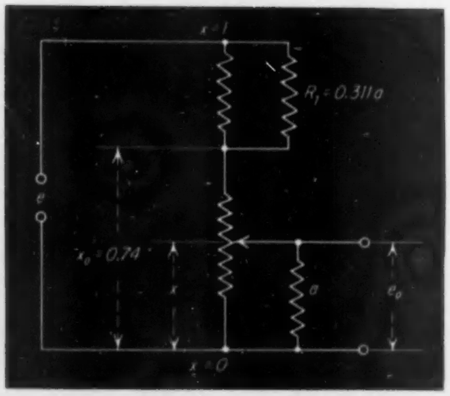
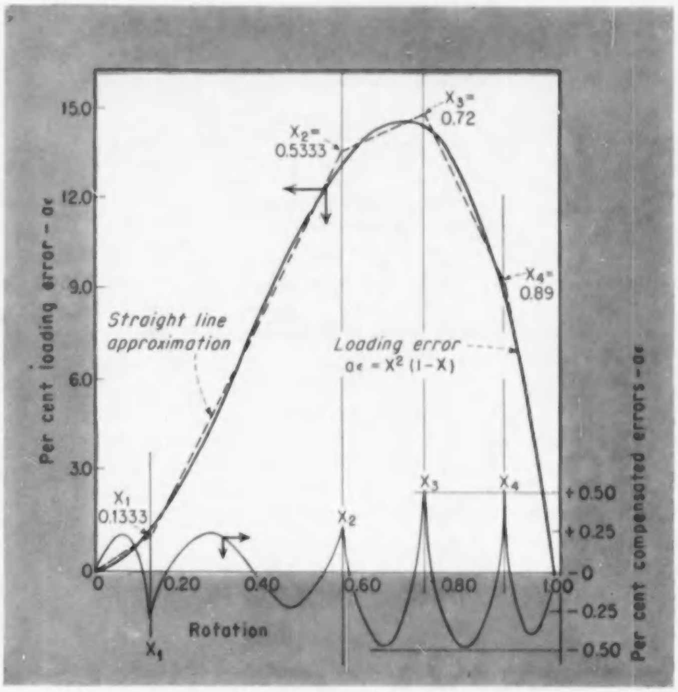


FIG. 1. Loaded linear pot with one-tap compensation. Values derived from Reference 1.



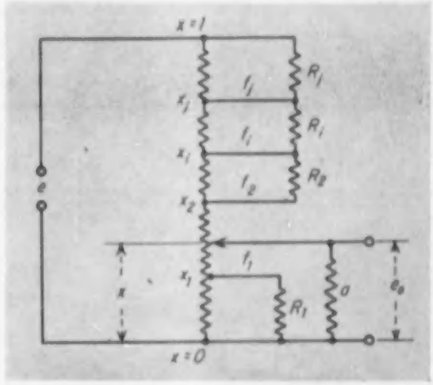


FIG. 3. Generalized multiple-tap design, shown here with four taps.

FIG. 2. Plot of error function with straight-line approximation to determine tap locations for four-tap design. Lower curve shows errors after compensation.

Using the graphical methods described in Reference 1, it can be shown that at least four taps are needed to limit the loading errors to the best resolution of a single-turn pot, where this resolution is taken as 0.025 percent. Briefly, this is accomplished in the following manner.

The desired potentiometer output function, f, is given approximately by the relation

$$f = X + \epsilon_s = X + X^2(1 - X)/a \tag{1}$$

where

ϵ_s = loading error

so that the error function can be expressed by

$$\epsilon_s = X^2(1 - X)/a \tag{2}$$

Thus, the object of adding compensating shunt resistors is to cancel this error function for the complete travel of the potentiometer, within allowable accuracy limits.

Figure 2 shows an expanded plot of the error function. To determine the required number of taps, draw approximately straight lines through this plot, such that the maximum difference between each straight line and the curve is the desired tolerance. The number of straight lines required to approximate the curve and still stay within the required tolerance determines the number of taps, and the intersections of the straight lines give the desired tap locations, X_i. Figure 3 shows a typical multiple-tapped potentiometer and indicates nomenclature.

The values of the shunting resistors are then calculated[2] by the following approximate relationship as derived at the end of the article:

$$\frac{R_i}{a} = \frac{X_j - X_i}{a(S - S_{ji})} \tag{3}$$

where

X_j, X_i = adjacent tap locations

S = maximum positive slope of any straight line drawn through ϵ_s

S_{ji} = straight-line slope between adjacent taps X_j and X_i

R_i = shunting resistor across taps X_j and X_i

The graphical results obtained in Figure 2 (plot of compensated errors) show that it is possible to limit the loading errors to 0.25 percent/a for values of X between 0 and 0.55, provided the error is increased to 0.50 percent/a for the second half of the potentiometer travel. For a load ratio of 20, these errors range from 50 to 100 percent of potentiometer resolution, where this resolution is taken as 0.025 percent. To insure a minimum loading error of 0.25 percent/a everywhere in the travel, another tap and resistor must be added to the upper half of the potentiometer. This five-tap design is discussed later.

Details of Four-Tap Design

The optimum tap locations can be estimated graphically from the plot of the error function in Figure 2 as

$$X_1 = 0.1333$$
$$X_2 = 0.5333$$
$$X_3 = 0.72$$
$$X_4 = 0.89$$

Then, the required values of the error function ϵ_s are calculated at the taps. The allowable loading errors are added or subtracted from the value of the

Table I
SUMMARY OF FINAL DESIGN PARAMETERS

TAP LOCATION	SHUNT RESISTOR VALUES		MAXIMUM ERROR, $a\epsilon_m$
	ONE TAP – a > 10		
$X_1 = 0.74$	$R_1 = 0.311a$		1.9 percent
	TWO TAPS – a = 20		
$X_1 = 0.20$	$R_1 = 0.66a$		0.5 percent
$X_2 = 0.80$	$R_2 = 0.66a$		
	FOUR TAPS		
	a = 100	**a = 20**	
$X_1 = 0.1333$	$R_1 = 0.647a$	$R_1 = 0.653a$	
$X_2 = 0.5333$	$R_2 = 0.831a$	$R_2 = 0.795a$	0.25 to 0.50 percent
$X_3 = 0.720$	$R_3 = 0.261a$	$R_3 = 0.261a$	
$X_4 = 0.890$	$R_4 = 0.097a$	$R_4 = 0.096a$	
	FIVE TAPS – a = 100		
$X_1 = 0.125$	$R_1 = 0.603a$		0.25 percent
$X_2 = 0.540$	$R_2 = 0.707a$		
$X_3 = 0.690$	$R_3 = 0.244a$		
$X_4 = 0.810$	$R_4 = 0.131a$		
$X_5 = 0.916$	$R_5 = 0.072a$		

NOTE: For other values of a use above values for R_i as first estimate, then calculate the error at tap, and reestimate R_i as shown in Table II.

Table II
CHECKING CALCULATIONS FOR FIVE-TAP DESIGN WITH LOAD RATIO OF 100

FIRST ESTIMATE

Estimated error at tap multiplied by load ratio	Tap X_i	Error Ordinate af_i	Slope aS_i	$a(S - S_i)$	$(X_j - X_i)$	R_i/a	Actual error at tap, percent	Difference between est. and act. error
−0.0020	0.125	0.0117	0.0936	0.3064	0.125	0.606	−0.0021	+0.0001
+0.0021	0.540	0.1362	0.3000		0.415		+0.0017	+0.0004←
+0.0021	0.690	0.1497	0.0900	0.2100	0.150	0.714	+0.0019	+0.0002←
+0.0023	0.810	0.1269	−0.1900	0.4900	0.120	0.245	+0.0022	+0.0001
+0.0023	0.916	0.0727	−0.5113	0.8113	0.106	0.1307	+0.0022	+0.0001
	1.000		−0.8655	1.1655	0.084	0.0721		

Note: $S = 0.3000$

REESTIMATE

Because of excessive differences in error as noted above, add 0.0004 to $af_i = 0.1362$ at $X_i = 0.540$, and 0.0002 to $af_i = 0.1497$ at $X_i = 0.690$. Run through the calculations again as follows:

−0.0020	0.125	0.0117	0.0936	0.2074	0.125	0.6027	−0.0021	+0.0001
+0.0021	0.540	0.1366	0.3010		0.415		+0.0022	−0.0001
+0.0021	0.690	0.1499	0.0887	0.2123	0.150	0.7065	+0.0022	−0.0001
+0.0023	0.810	0.1269	−0.1917	0.4927	0.120	0.2436	+0.0022	−0.0001
+0.0023	0.916	0.0727	−0.5113	0.8123	0.106	0.1305	+0.0023	0.0000
	1.000		−0.8655	1.1665	0.084	0.0720		

Note: $S = 0.3010$

All ordinate and slope values refer to those of the approximating straight lines.

error function at each point, as dictated by the approximating straight lines. This gives the values of f_1, f_2, f_3, and f_4, used in calculating the shunt resistance values. Similarly, the standard slope S, and each slope S_{ft} are calculated from the values of the function f_t at each tap. With these parameters established, it is possible to calculate each R_t/a from Equation 3.

Since the assumed expression for f, Equation 1, is more nearly exact for high load ratios, the design values for R_t are calculated using a load ratio of 100. Then as a check, the actual voltage ratios existing at the taps can be calculated from the resulting multiple-tap potentiometer network. Although these calculations are not included for this four-tap design, Table II shows the procedure in detail for the five-tap design discussed later.

Following this method, the computed errors at the tap points normally differ only a few parts per million from the estimates, for a load ratio of 100. If this difference is excessive at a particular tap, reestimate the resistor value to bring the error inside the allowable tolerance. For example, in this particular circuit, R_1/a was reestimated to equalize the errors at the first two taps at plus or minus 0.0024 percent (for $a = 100$) as estimated.

The same values of R_t/a can then be used for a load ratio of 20. As shown by the summarized values for the four-tap design as listed in Table I, readjustment of the R_t/a values is again necessary to bring the actual loading errors inside the permissible tolerance. A similar technique can be followed when using the four-tap design with any load ratio, since reestimation is simple starting with the R_t/a values for a load ratio of 100.

As mentioned previously, Figure 2 includes a plot of the graphically estimated compensated loading errors as a function of potentiometer travel. Note the cusps at the taps, and the intentional increase in loading error for X greater than 0.55. Although the designs given are not necessarily optimum because of possible inaccuracies in the graphical method, maximum compensated loading errors will always be less than plus or minus 0.50 percent/a.

Two-Tap Design

The two-tap design of Figure 4 is included because it shows an interesting approach. A series resistor, R_s, drops the voltage to the potentiometer to approximately 66.7 percent of e in the absence of load, but with the compensating resistors connected[1]. This gives a symmetrical error with maximum ordinates of about plus or minus 3.2 percent/a. The two taps and resistors then reduce this error to approximately 0.50 percent/a, about the same as the four-tap design. But although this design has fewer components than the four-tap method, it is not generally used since it presents an awkward scale factor and is not capable of delivering the maximum exciting voltage—a common requirement. The adjustment of R_s is quite critical, and all tolerances must be tight to achieve the desired loading error reduction.

Five-Tap Design

If a maximum loading error of 0.50 percent/a cannot be tolerated, then a five-tap design must be used. This will limit the error at any point in the travel to less than 0.25 percent/a. This design can be calculated by using Equation 2 and the approximating straight lines

$$y = m + nX$$

and restricting errors at the tap and elsewhere to less than 0.24 percent/a. The values of the shunting resistors can be determined from Equation 3, and the errors checked at the taps from the actual circuit for a loading ratio of 100.

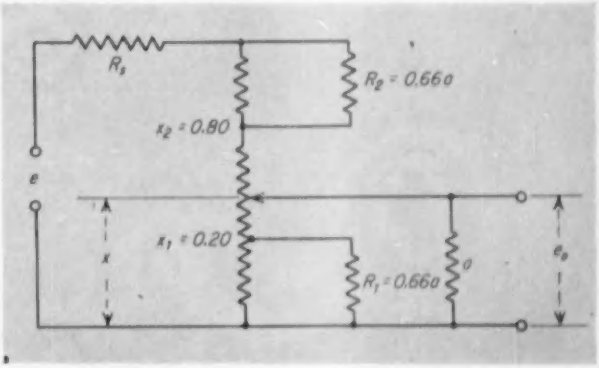


FIG. 4. Two-tap design with dropping resistor, R_s.

In the design discussed here, the actual voltage ratios checked with the predicted values to within a few parts per million. Nevertheless, the values of f_t at the taps were altered to account for these errors. As shown by the step-by-step procedure in Table II, the final design checked to within one part per million at each tap and a few selected checkpoints.

The resulting error curve (not shown) crosses zero 13 times and has a maximum amplitude of about plus or minus 0.24 percent/a. This represents a loading-error reduction of about 60 to 1 from the uncompensated design, and should be seriously considered for use in multi-turn potentiometers with load ratios of 10 or higher.

Miscellaneous Points of Interest

If maximum loading errors must be less than 0.25 percent/a, more than five taps and resistors must be used. While the design procedure would be identical to the five-tap method, to decrease loading errors to 0.1 percent/a or less it is estimated that

about 11 taps and resistors would be required. This complication is only warranted for three-turn or ten-turn potentiometers, or for load ratios less than ten. In addition, the tolerances on taps and resistors would be quite severe. The recommended tolerances for the above five-tap design are about plus or minus 0.001 of total potentiometer resistance for tap location, and about plus or minus 0.2 percent for the resistors. These tolerances can be tightened or relaxed, depending on desired compensation.

Note also, that the same taps as in the five-tap design plus a tap at X = 0.33 can be used to correct for the basic linearity errors of the potentiometer itself. To accomplish this, plot an error function consisting of the load ratio times the sum of the potentiometer errors and the loading errors. Then if the above design procedure is followed, the result is merely different values of resistors at the same taps. The purpose of the extra tap is to give some statistical guarantee that the potentiometer linearity errors between X = 0.125 and X = 0.540 could be corrected.

Note that the tap locations, X_i, and the shunt resistor values, R_i, are known beforehand since they depend only on the error function, ϵ_e, and the load itself. Hence, the resistors can be purchased before the potentiometer is made, and the taps can be welded when the potentiometer is wound. This should simplify the mass production of such designs.

Considerable phase or quadrature reduction for load capacity or inherent phase shift can also be effected by a similar design using taps and shunting capacitors. This design problem will be covered in a future issue of CONTROL ENGINEERING.

REFERENCES

1. *HERE'S A SHORTCUT IN COMPENSATING POT LOADING ERRORS*, J. Gilbert, "Control Engineering", February 1955.
2. *SHUNTING CONTROLS LINEARITY*, B. C. Beach Jr., "Electronic Equipment", January 1955.

DERIVATIONS

Derive an expression for determining the value of each R_i (Equation 3 in text). Let f be the desired function of X. Assume that the maximum positive slope, S, occurs between taps X_2 and X_1. Let the desired function values at these points be f_1 and f_2, Figure 3. Then

$$S = \frac{f_2 - f_1}{X_2 - X_1} = S_{21} \tag{1a}$$

Denote the parallel resistance between two tap points X_3 and X_2 as R_{32}. Thus, for unity potentiometer resistance

$$\frac{f_3 - f_2}{f_2 - f_1} = \frac{R_{32}}{X_2 - X_1} \tag{2a}$$

From Figure 3

$$R_{32} = \frac{R_2(X_3 - X_2)}{R_2 + (X_3 - X_2)} \tag{3a}$$

Combining Equations 1a, 2a, and 3a gives

$$R_2 = \frac{f_3 - f_2}{S - S_{32}} \tag{4a}$$

where

$$S_{32} = \frac{f_3 - f_2}{X_3 - X_2}$$

Similarly, for any two adjacent taps X_i and X_j

$$R_i = \frac{f_j - f_i}{S - S_{ji}} \tag{5a}$$

where f_j and f_i are the desired function values at adjacent taps.

Substitute Equation 1a and Equation 2 (from the text) in Equation 5a and then simplify, remembering that ϵ_e now refers to the straightline approximations.

$$R_i = \frac{(X_j - X_i) + (\epsilon_j - \epsilon_i)}{S_{21} - S_{ji}} \tag{6a}$$

Dividing both sides by the load ratio, a, and ignoring $(\epsilon_j - \epsilon_i)$ in comparison with $(X_j - X_i)$ gives

$$\frac{R_i}{a} = \frac{(X_j - X_i)}{a(S_{21} - S_{ji})} \tag{3}$$

The numerator of Equation 3 is simply the difference in resistance of the adjacent taps across which R_i is connected, while each term in the denominator is the slope of the approximating straight lines of the error plot $a\,\epsilon_e$.

And Now, an Example

Consider the one-tap design shown in Figure 1. Reference 1 showed that an error of + 0.019/a was permitted at the tap X_0 = 0.74. Substituting these values in Equation 2 gives

$$a\epsilon'_e = (0.74)^2\,(1 - 0.74) + 0.019 = 0.161$$

The maximum positive slope of the error function is therefore

$$aS = 0.161/0.74 = 0.2176$$

The slope of the error function between X_0 = 0.74, and X_1 = 1.0 is

$$aS_{10} = -\,0.161/(1 - 0.74) = -\,0.6192$$

Therefore

$$\frac{R_i}{a} = \frac{(X_1 - X_0)}{a(S - S_{10})} = \frac{(1.0 - 0.74)}{(0.2176 + 0.6192)} = 0.311$$

which agrees with the results of Reference 1 as noted in Figure 1.

SELF-REGULATION: The Inherent Behavior of a Process

Frequently the terms self-regulation and no self-regulation appear in the discussions on process control (see Geraldine A. Coon's articles in CONTROL ENGINEERING, May and June, 1956). Author Holzbock elaborates, with a unique approach, on the concept of self-regulation, basing his analysis on a simple liquid-level process with a single time constant.

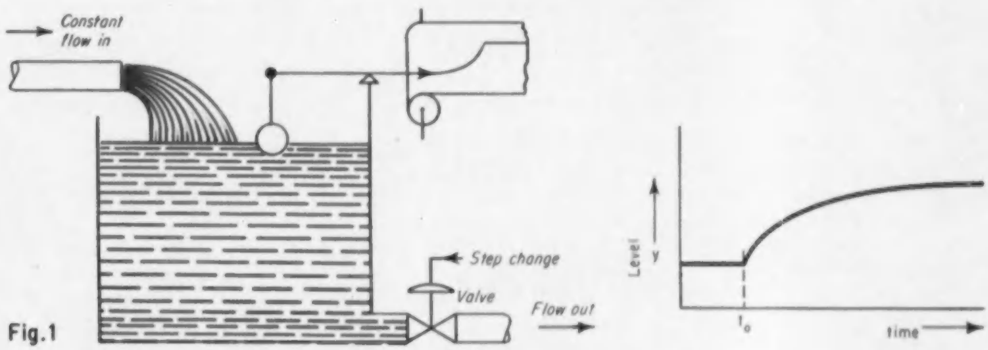


Fig.1

W. G. HOLZBOCK, Askania Regulator Co.

The behavior of a process under closed-loop control depends on its behavior under open-loop conditions. Certain processes exhibit self-regulation even in an open loop. That is, even without control, their inherent behavior causes the controlled variable to automatically attain a new balance position following a disturbance. Other processes have no self-regulation, and following a disturbance, the controlled variable changes indefinitely.

Analysis of a process under closed-loop control is frequently discussed in terms of time constants. But the time constant of a process depends on the factor of self-regulation. Therefore, knowing whether a process behaves with or without self-regulation gives some insight to the problem of control.

Consider as a single-capacity (single-time-constant) process the liquid level in a tank. This process may be arranged in two ways: one way gives self-regulation and the other does not. A review of the process yields some physical meaning to the concept of self-regulation and its relationship to time constant.

Process With Self-Regulation

The controlled variable of the process shown in Figure 1 is the liquid level in a cylindrical tank. Here liquid enters the tank at a constant flow rate. The rate at which the liquid leaves the tank depends on the position of the valve stem and the level of the liquid. Assume that prior to a disturbance at the valve the flow in equals the flow out. Therefore the level is constant. This is shown by the short horizontal portion of the graph at the right in Figure 1, above. Suppose at t_o a step change in valve position, introduced by manual means, closes the valve slightly. Now the flow in exceeds the flow out and the level in the tank rises. But as the level rises the hydraulic head increases also. The increase in head causes the flow out to increase. Eventually, at this new valve position, the flow in again balances the flow out. Thus a new balance has been reached without closed-loop control. The ability to reach balance in this manner is known as self-regulation.

Process With No Self-Regulation

Now consider the same tank filled and emptied in the manner shown in Figure 2. Here a pump main-

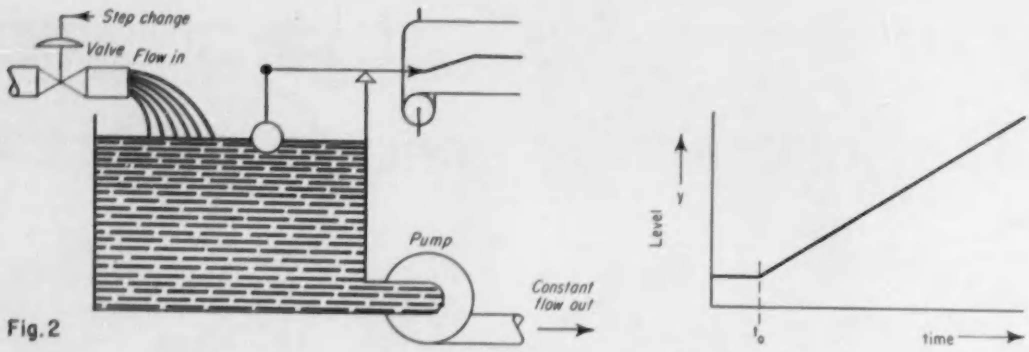


Fig. 2

tains the output flow constant and independent of the level, and a valve controls the flow in. Suppose the level is initially at equilibrium. A step change at the valve increases the input and the level rises. Because the output remains constant, a new balance is never reached. The change in level with respect to time is shown in the right of Figure 2.

Mathematical Derivation of Self-Regulation

The initial flow rate change is expressed as a fraction a of the fully-opened valve's flow-rate change for a step-change disturbance. Figure 3 illustrates the unbalance flow x resulting from a step change in valve position a. At balanced conditions the final value of x equals zero. Thus x expresses the difference between the unbalanced and balanced flows.

The final level y equals a fraction of some arbitrary maximum level. For a step change in valve position:

$$x = a - by \tag{1}$$

which means that the change in flow rate is proportional to the change in valve position minus the level change. Here the level y is multiplied by the coefficient b, where b expresses the effect the level change has on the flow change. In other words, b tells how fast a new balance will be obtained. Coefficient b, therefore, is the factor of self-regulation.

For x equals zero, Equation 1 becomes

$$a = by \tag{2}$$

which shows that the final level attained equals a/b.

The rate of change of level depends on the magnitude of the step change x at the valve. Thus:

$$\frac{dy}{dt} = cx \tag{3}$$

where c is a proportionality factor. Under initial conditions a equals x. Therefore;

$$\frac{dy}{dt} = ca \tag{4}$$

which shows that c is the initial level rate of change per fractional change of valve position.

Substituting Equation 1 into Equation 3 yields:

$$\frac{dy}{dt} = c\,(a - by) \tag{5}$$

The solution of this differential equation is:

$$y = \frac{a}{b}\,(1 - e^{-bct}) \tag{6}$$

When $t = 1/bc$, Equation 6 becomes:

$$y_{t=1/bc} = \frac{a}{b}\,(1 - e^{-1}),\ \text{or}\ y_{t=1/bc} = 0.632\,\frac{a}{b} \tag{7}$$

But a/b was previously identified as being equal to y, the final level. Since level y reaches 63.2 percent of its final value at $t=1/bc$, then $t=1/bc$ equals the time constant T of the process. Therefore $T=1/bc$ shows that the time constant is a function of two parameters:

- ▸ b, the factor of self-regulation, and
- ▸ c, the initial speed of response of the process per fractional change of valve position.

Equation 2 shows that the factor of self-regulation b is the proportion between the valve-position step change and the final level obtained. The process shown in Figure 1 does reach some finite final level. Therefore b does not equal zero. Then from Equation 7, the time constant for this process must be some finite value and the process does have self-regulation. Figure 2 shows the converse.

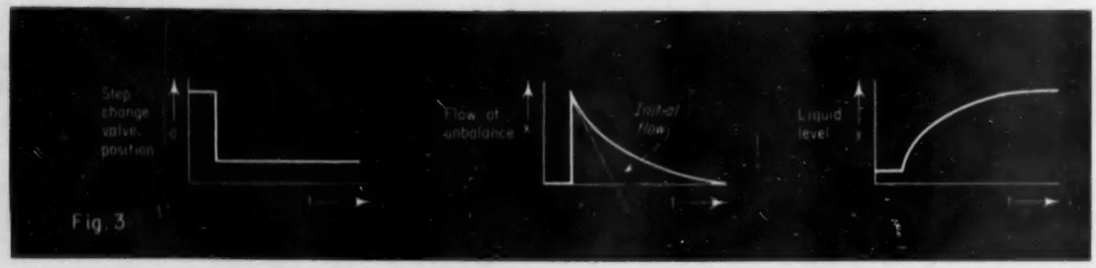


Fig. 3

Used Strategically — Frequency Response Improves IN-FLIGHT STABILITY

This case history of an autopilot development using frequency-response techniques shows how these techniques pinpointed sources of instability within the control system and how they explained the wide variance between simulated and actual aerodynamic motions. The strategy used by the author in circumventing the instability of his airborne "process" applies equally well to any automatically controlled industrial process. He analyzes theoretical operation of the controlled system for likely causes of trouble, and then installs instrumentation to measure the actual behavior. Results: fast location of trouble and immediate redesign of the control equipment.

BOUDE C. MOORE Douglas Aircraft Co., Inc.

Every servo engineer at some time faces the problem of a misbehaving servo system. What techniques can he use to achieve desired system performance with as few hardware changes and in as little time as possible?

This problem is especially important to the designers of autopilots, to whom flight test time is costly. Flight test programs concentrate on aerodynamic and engine problems. Autopilot test flights have low priority even though the new faster and larger planes demand more complicated functions from their autocontrol systems. Scrapping familiar circuitry in favor of the latest transistor and magnetic amplifiers adds other complications too. Obviously, then, the autopilot design engineer must make the best use of the flight test time allotted to his project.

A newly designed aircraft requires a newly designed autocontrol system because the control system must satisfy the plane's unique aerodynamic design. Although certain predictions about the plane's performance are based on theoretical information, the real facts about stability and accuracy show up in the flight test of the plane. Tracing development of an autopilot for a new high-speed aircraft brings out problems that arise in going from the design phase into the flight-test phase.

(Because of security requirements the author cannot reveal the aircraft under development nor disclose certain numerical data. Ed.)

In this development program the design of the prototype autopilot was based on aerodynamic equa-

FOLLOW THESE STEPS TO IMPROVE SYSTEM PERFORMANCE

1. PREPARE FREQUENCY RESPONSE OF PREDICTED BEHAVIOR. In addition to the basic equations, the frequency-response and the transient-response curves should be provided for each of the major branches of the system.

2. OBTAIN FREQUENCY RESPONSE OF ACTUAL BEHAVIOR. Record the system's performance and convert data into frequency-response plots for the major branches of the system.

3. ANALYZE RESULTS FOR CAUSES OF DISCREPANCY. Frequency-response plots make it very easy to pinpoint discrepancies between predicted and actual behavior. The original design of the system was based on the best information available. The presence of a problem means the original information does not represent the system under test, and redesign based on this information has a low probability of success.

4. REDESIGN SYSTEM BASED ON RESULTS OF ANALYSIS. Once causes of trouble have been determined, immediate redesign (based on the actual test data of the system) can be undertaken.

5. REVISE PREDICTED BEHAVIOR. It is certainly necessary, for future design purposes, to correct the original equations and bring computer solutions in line with measured data. However, there is no need for equipment redesign and development to await this time-consuming procedure.

TABLE I

TROUBLE SOURCES IN PITCH CHANNEL

(A) (1) Basic phugoid equations

(a) $(C_D + S)\mu + \frac{C_L}{2}\theta = 0$

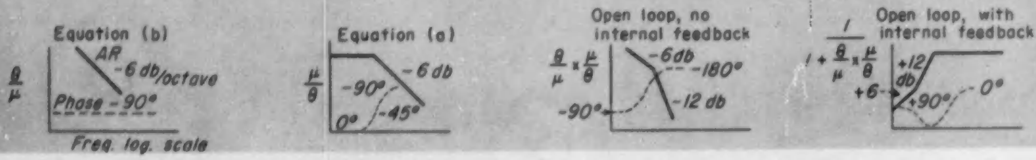
(b) $C_L \quad \mu - S\theta = 0$

Flow graph

(a) expresses effect of θ on μ

(b) expresses effect of μ on θ

Where: μ = airspeed ratio (wind axis)
θ = pitch angle (wind axis)
C_D = drag coefficient
C_L = lift coefficient
S = Laplace operator
Angle of attack assumed constant



(B) (2) Relation between pitch angle and altitude

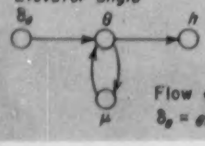
(a) $a_Z = \dot{\omega} - \mu q$

(b) $h = S^2\left[\dot{\omega} - \mu q\right]$

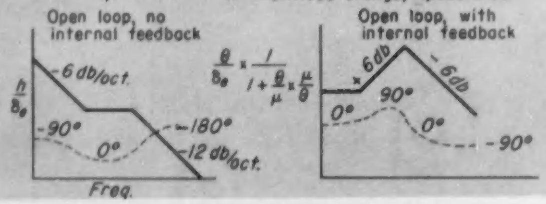
$$\frac{h}{\delta_e} = \frac{\theta}{\delta_e} \times \frac{h}{\theta} \times \frac{1}{1 + \frac{\theta}{\mu} \times \frac{\mu}{\theta}}$$

Where: a_Z = vertical acceleration, space axes
$\dot{\omega}$ = vertical acceleration, body axes
q = pitch rate, body axes
h = altitude change, space axes

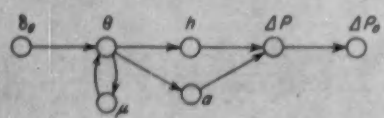
(3) $\frac{\text{Altitude}}{\text{Elevator angle}}$ for typical airplane



Flow graph
δ_e = elevator angle

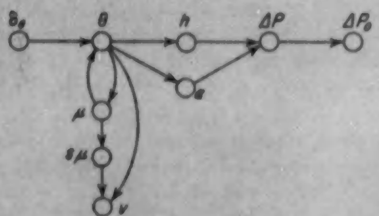


(C) (4) Errors in measuring altitude



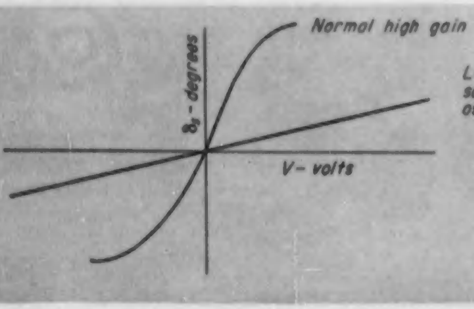
a = angle of attack
ΔP = pressure at static inlet
ΔP_o = pressure at altimeter
$\frac{\Delta P}{a}$ = position error
$\frac{\Delta P_o}{\Delta P}$ = pressure lag

(D) (5) Errors in measuring pitch angle

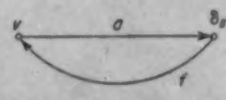


$s\mu$ = longitudinal acceleration
v = pitch gyro output
$\frac{v}{\theta}$ = pitch gyro output due to θ
$\frac{v}{s\mu}$ = pitch gyro output due to effect of $s\mu$ on gyro erection

(E)



Low gain when saturated by oscillations



$$\frac{\delta_e}{v} = \frac{a}{1 + af}$$

An unstable aerodynamic loop, contained in branch **d** of Figure 1B, results in a phugoid oscillation of very low frequency. Typical periods range from 10 to 100 sec. The pilot found these oscillations easy to damp and it is not a serious problem in normal flight. But with autopilot control, complete damping becomes difficult at all conditions of airspeed, altitude, weight, and center of gravity.

The unstable phugoid loop enters directly into the pitch angle/elevator angle and altitude/elevator angle transfer functions (branches **cd** and **cde** of Figure 1B). Consequently these branches have the interesting characteristic of going to infinity at the phugoid frequency: output is produced with no input. Fortunately the same peak occurs in both the pitch and altitude loops.

Errors in measurement create a source of trouble as in this case of measuring altitude. Pressure at the static inlet is affected by both altitude and angle of attack. The effect on angle of attack is known as position error, which may be a positive or negative correction, depending on the location of the inlet. A time lag exists between the inlet pressure and the instrument pressure. Errors of this type are difficult to calculate and often ignored in the initial analysis. Flight tests determine whether they are indeed negligible.

Another instrumentation error arises in the measurement of the pitch angle. The output of the altitude gyro is affected by the fore and aft accelerations of the airplane. The erection mechanism of the gyro senses these accelerations as a changing direction of gravity. The false correction appears as a pitch angle. During long period of phugoid oscillation these erroneous changes in pitch angle may become an appreciable part of the measurement.

Local oscillation in one of the loops creates trouble, too. In branch **a**, illustrated by the static sensitivity curve and the flow graph, local oscillation causes the amplifier to saturate, but the system continues to function. However, the overall gain is seriously reduced below that required for good design. Reduced gain because of local oscillation actually occurred in the prototype autopilot, and became apparent through analysis of the frequency-response curves obtained from flight-test results. Subsequent trouble-shooting of the equipment in branch **a** then isolated the immediate cause of the trouble and aided redesign.

tions obtained from wind-tunnel data. Simulation of these equations on an analog computer, together with a full-scale mock-up of the airplane's control mechanisms and a prototype of the autopilot amplifier, aided investigation. Here, the computer output fed the amplifier that drove the control surfaces. Control surface motions, fed back into the computer, completed the simulation.

This arrangement permitted quick evaluation of how the prototype autopilot, at any combination of its settings, controlled the aircraft over a wide range of simulated operating airspeeds and altitudes. From these data the best autopilot settings were selected to determine whether this prototype would confirm predicted performance in flight.

FLIGHT TESTING THE AUTOPILOT

In the first flight test of the autopilot it responded to large disturbances very much as predicted—fast and well-damped. However the autopilot did not fly the airplane straight and level, but in long, slow oscillations with a period of 10 to 20 sec.

These oscillations occurred along the pitch, yaw, and roll axes. They are a common problem. In this case, the high speed and the large inherent dead zone in the hydraulic control system aggravated conditions, because corrective action on the plane's control surfaces only required small displacements on the order of a few hundredths of a degree.

During the initial flight tests the autopilot was adjusted in accordance with optimum settings predicted by the simulated system. Next came flights using full range of adjustments available in the autopilot. These demonstrated that the existing autocontrol system could not stabilize the plane.

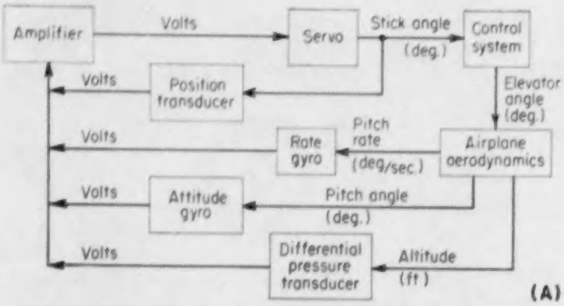
RANDOM REDESIGN

The initial search for a cure to the instability problem succeeded in disclosing a number of deficiences. For example, the servo's output shaft twisted under load resulting in an undesirable dead zone, so that a certain torque level was required to produce any useful output motion. A similar dead zone was found in the altitude sensor—small altitude changes produced no changes in output voltage. Either of these deficiencies could have caused the oscillations, but correcting them failed to cure the instability problem. This phase of redesign resulted in little improvement for the effort.

SYSTEMATIC REDESIGN

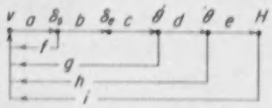
Because the source of instability still remained hidden it was then decided to solve the problem on a logical basis: to compare the basic theoretical calculations with the actual behavior of the plane under flight conditions. Frequency-response techniques are an appropriate tool for comparison because they allow the complete system to be analyzed,

FIG. 1: A PITCH CHANNEL'S BLOCK



(A)

. . . AND ITS FLOW GRAPH



(B)

Where: v = voltage input to amplifier
δ_s = pilot's stick position
δ_e = elevator position
$\dot{\theta}$ = airplane pitch rate
θ = airplane pitch angle
H = airplane altitude

Transfer functions:

Each branch shown may be made up of several smaller components — including feedback loops.

$a = \frac{\delta_s}{v}$ $d = \frac{\theta}{\dot{\theta}}$ $g = v/\dot{\theta}$

$b = \frac{\delta_e}{\delta_s}$ $e = \frac{H}{\theta}$ $h = v/\theta$

$c = \frac{\dot{\theta}}{\delta_e}$ $f = v/\delta_s$ $i = v/H$

By inspection, equations of motion may be written as:

$$\frac{H}{v} = \frac{abcde}{1 + af + abcg + abcdh + abcdei}$$

providing sufficient information to locate trouble. Since the system was already oscillating, these techniques were easily applied.

The airplane equations of motion used in the original design yielded the theoretical frequency-response characteristics of the individual branches of the system. But obtaining the actual transfer functions under flight conditions required considerable auxiliary instrumentation.

Theoretical Transfer Functions

A typical autopilot contains two control channels, one for pitch, and one for yaw and roll. Figure 1A illustrates, by use of the familiar block diagram, the configuration of the pitch channel, and shows the individual branches in terms of the channel's equipment and connections. However, test engineers prefer the flow graph (Figure 1B) for describing the system. They are trained to write the system equations by inspection from such flow charts[1]. Each branch of this graph can be represented by static sensitivity curves, as in Figure 2, and by frequency-response curves, as in Figure 3. For effective control of altitude, the gain of the altitude loop ($abcdei$ in Figure 1B) must be much greater than the other feedback loops combined. Therefore, at low frequencies, the denominator $1+af+abcg+abcdh+abcdei=H/V=1/i$. Thus the system low-frequency behavior depends on branch i, the altitude-sensing unit and voltage feedback.

However, the altitude loop contains two integrations—branches d and e. Therefore, as frequency increases the gain will decrease at 12 db/octave and the phase angle will reach minus 180 deg. At some frequency the system will oscillate unless stabilized. In normal stabilization procedure, the pitch feedback voltage predominates at medium frequencies, and the pitch rate voltage and the stick position voltage predominate at successively higher frequencies.

But in the prototype system instability still existed, indicating some source of trouble. As noted in Figure 1B, each branch may be made up of several smaller components, including feedback loops. Some of these branches are investigated in Table I. Trouble sources include inherently unstable aerodynamic loops, low gains in the control system, and instrumentation errors in measuring the aircraft's position during flight. Knowing, from theoretical considerations, where trouble may occur helps locate additional instrumentation to evaluate these transfer functions under flight conditions.

Once the individual branches and their transfer functions were developed, the airplane equations of motion used in the original autopilot design were solved to give appropriate numerical values to the frequency-response curves of the individual branches. Now the predicted motions, based on wind-tunnel and theoretical data, could be directly compared with the actual airplane motions as determined from instrumented flight tests.

In-Flight Transfer Functions

The airplane was suitably instrumented to define the aerodynamic, electronic, and hydraulic portions of the system. An oscillograph recorded all measurements, subsequently yielding both amplitude ratio and phase shift information as a function of frequency. The autopilot itself, already unstable, served as the usual sine wave generator needed for frequency-response tests. Here, the frequency of oscillation could be varied from 0.05 to 2 cps simply by varying the autopilot settings. This range of frequencies covered the entire spectrum of interest.

Typical recorded measurements for the aerodynamic portion dealt with rate of roll, rate of yaw, rate of pitch, lateral and longitudinal acceleration,

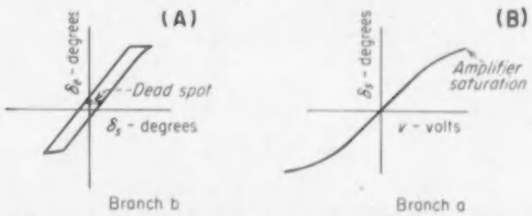
and control surface positions. For other data, stick angle and clutch current were used.

Recorded data showed considerable scatter. Factors contributing to this scatter were nonsymmetrical pseudosinusoidal oscillations of very small amplitude, and variations in the system due to vibration, wear, and part changes. Probable error of most measurements was 15 percent.

These recorded oscillations allowed measurement of the individual branch transfer functions. For example, Figure 4 shows a short portion of the oscillograph record which gave the plane's altitude and its elevator position. This information defined branches *cde* of Figure 1B and Table 1B. Since the autopilot was unstable, adjustment of its pitch angle and pitch rate settings changed the frequency of oscillations at which the amplitude ratio and phase shift of the *altitude/elevator position* transfer function was plotted.

Figure 5 shows part of the oscillograph record used in obtaining roll-yaw oscillations. Here branches concerned must be defined, for rate of roll has components from both aileron and rudder motion.

Several hundred feet of oscillographic record may



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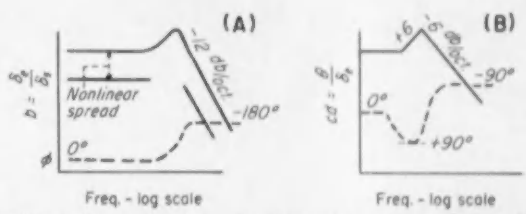
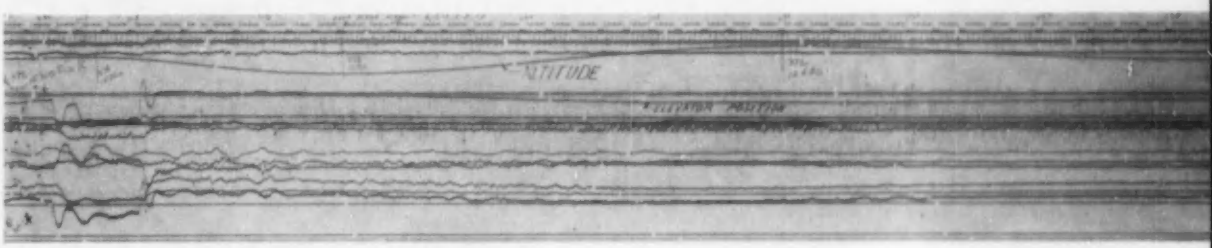


FIG. 3. Figure 3A shows the frequency response characteristics of branch b. Note the spread in the curve resulting from the extreme nonlinearity (backlash) in this branch. Figure 3B illustrates the combined frequency response of c and d.



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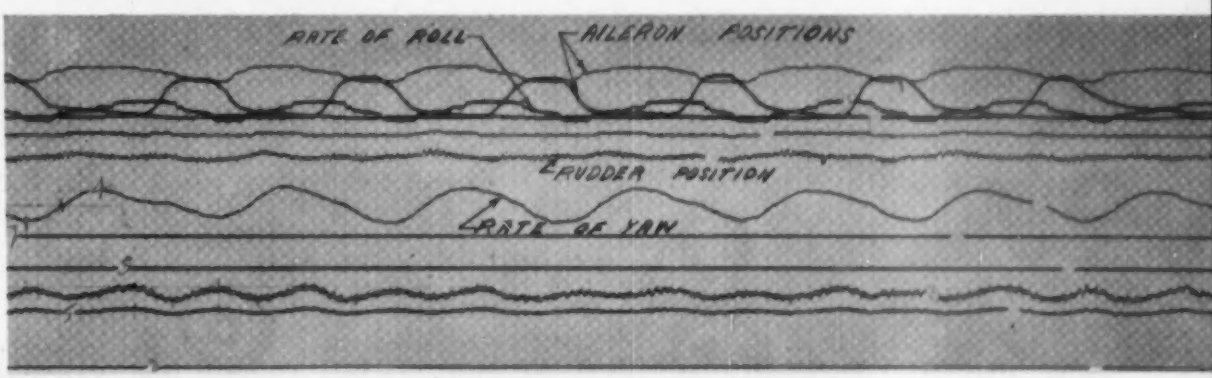

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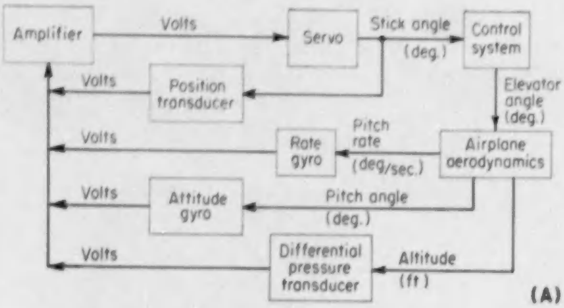

(A)

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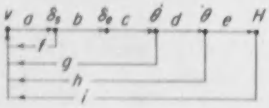

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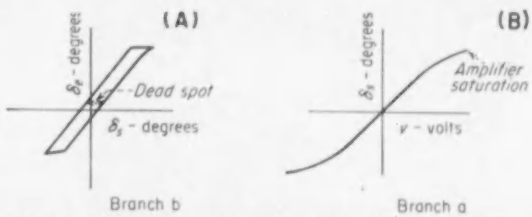

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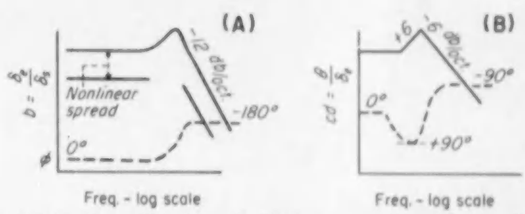

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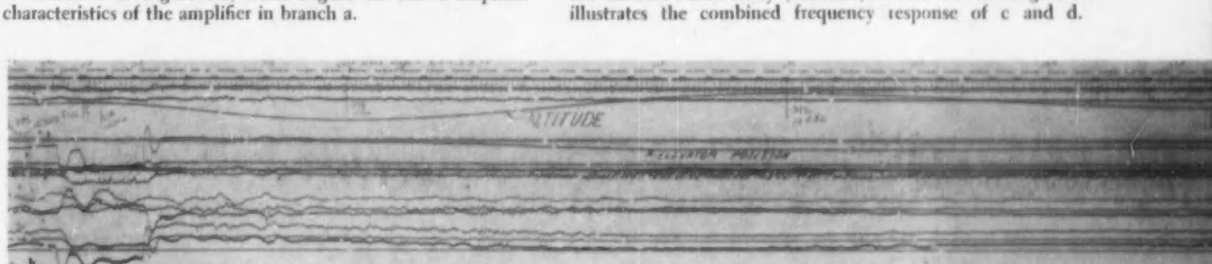

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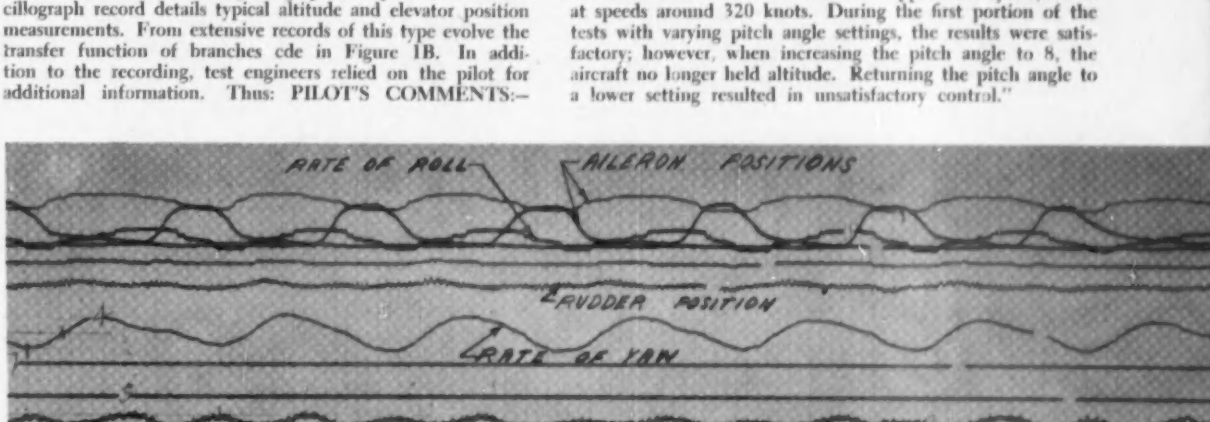

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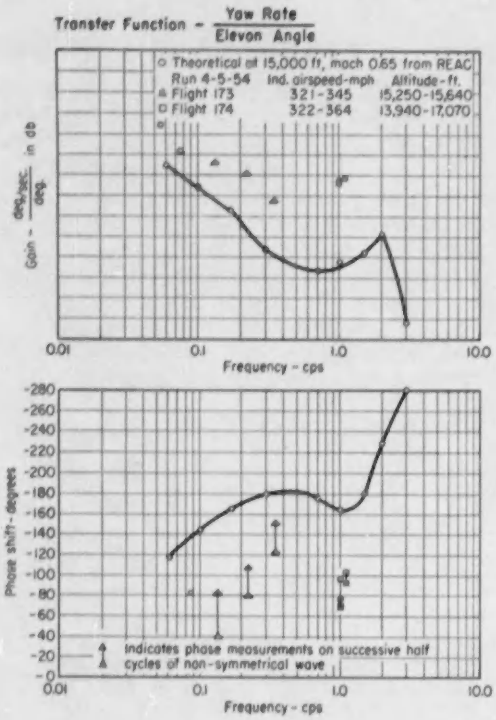


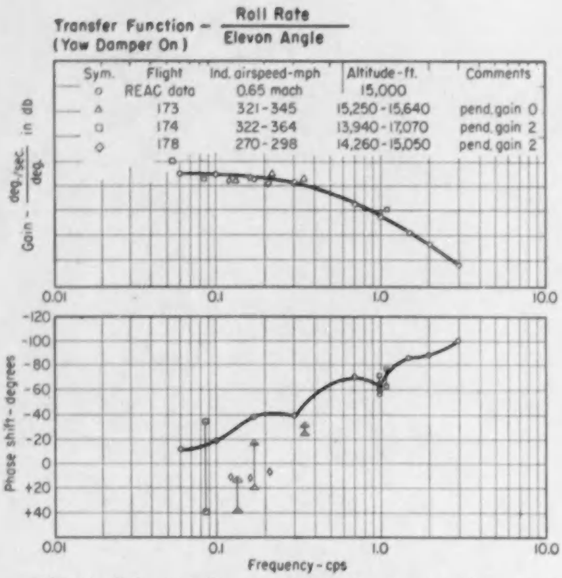


FIG. 6. Roll rate/aileron angle transfer function shows good correlation between computed data and three groups of flight test data. Thus predicted aerodynamic behavior is confirmed.

FIG. 7. The yaw rate/aileron angle transfer function shows a discrepancy between predicted and flight-test data, thus revealing an inaccuracy in the original information.

be needed to obtain sufficient information for even a few plotted points on frequency-response curves. And only when these curves are plotted can the results be used to prove whether the flight-test data conform to the predicted data and to locate the instability.

Figures 6 and 7 consolidate a portion of the recorded information obtained during the flight tests. These frequency-response plots compare the predicted data (obtained on the analog computer using theoretical and wind-tunnel results) with data obtained from flight tests. Figure 6, the transfer function of *roll rate/aileron angle*, shows excellent correlation in the amplitude ratio among all four tests. The discrepancy in the phase-shift measurements are due to instrumentation difficulties in measuring small variations and nonsymmetrical oscillations in the recorded data. In general, flight-test results in Figure 6 verify the predicted behavior of this aerodynamic branch.

However, the *yaw rate/aileron angle* transfer function in Figure 7 shows a wide discrepancy between predicted and flight-test data. Thus use of the predicted response for this aerodynamic branch resulted in the incorrect design of the autopilot's yaw-control section, since the equations of motion did not actually represent flight behavior.

SUMMARY OF TEST RESULTS

The flight tests investigated the aerodynamic and control branches of the airplane for the pitch channel and the roll-yaw channel. The following facts emerged from the resulting data:

Pitch Control

1. The aerodynamic branches behaved as predicted. No modification in the theoretical data was required.
2. A very low gain was found in branch a of Figure 1B. Further investigation showed an oscillation of about 50 cps, which saturated the amplifier and reduced the gain (as shown in Table IE.)
3. The hydraulic control system, branch *b*, showed very low gain and large phase lags.

Because the difficulties causing instability were now located, a realistic redesign and improvement of this system could be undertaken.

Yaw-Roll Control

4. The rudder amplifier and control system behaved as predicted.
5. The aileron amplifier and control systems showed the same deficiencies as found in the elevator (pitch) system. The hydraulic and electronic equipment was redesigned accordingly.
6. The *roll angle/aileron angle* (yaw damper on) transfer function behaved as predicted. No modification of predicted data was required.
7. The *yaw angle/aileron angle* (yaw damper on) transfer function was significantly greater than predicted, especially at high frequencies. Thus this portion of the predicted data was revised.

REFERENCE

1. *FEEDBACK THEORY—SOME PROPERTIES OF SIGNAL FLOW GRAPHS*, Samuel J. Mason. "Proc. IRE", Sept. 1953.

Control Elements in the Computer

THE GIST: Conceptually, digital computers have four elements: a memory, an arithmetic element, input-output elements, and a control element. The memory retains information. It may be used to store the program (the instruction sequence that the computing system is to follow), the data to be used in the sequence, and the intermediate results of computations. The arithmetic element does the addition, subtraction, multiplication, division, and other operations that have been specifically built into the repertoire of the computer. It has very limited storage capacity, retaining only the information required to perform the function at hand. The input-output units are the communications links between the computer and the people or equipment outside the computer.

The memory and arithmetic unit have been described in previous articles. Input and output equipment will be described next month. We now consider the control element that interprets the instructions of the program and coordinates the memory, arithmetic, and input and output elements in carrying out these instructions.

This article shows how the control enables the computer to carry out an instruction sequence. First, the general function of the control is discussed. Next, various instruction structures that may be used with a control are covered. Following this, the design techniques used in constructing a control are illustrated in detail by a simple example. Finally, application of these techniques to the design of a control is outlined.

E. E. BOLLES and H. L. ENGEL
The Ramo-Wooldridge Corp.

The control element is the computer's coordination center. Its function may be understood by considering the actions that a human performs in manual computation and in using a desk calculator to do the same computation. Such a computation might be the evaluation of the function $Y = 17.5X + 38.3$ for a number of values of X, as illustrated in Table I.

The desk calculator example illustrates some of the features of control that are duplicated in electronic digital computers:

1. The numbers used in the calculation are stored in the calculator.
2. Pushing one button labeled "Multiply" causes the machine to refer to two numbers stored in registers.
3. This same operation causes these two numbers to be multiplied together.
4. The result is automatically stored in a particular portion of the machine where it is available for use in following operations. Pushing a single button brings about a very complicated action of the machine to produce a useful result.

In the sequence-controlled calculator or electronic digital computer, the manual steps of the desk calculator procedure are done by the computer itself. The computer automatically refers to operands, initiates processes such as multiplication or addition, and stores results. The control is the portion of the machine that causes these functions to be performed.

A typical instruction might call for a number to be selected from storage address 207, added to a number that is already in an arithmetic element, and a new instruction to be read from storage address 846. Another might request a number to be read in from input tape unit number 3 and transferred to the arithmetic element, and a new instruction obtained from storage address 208. More generally, a control must at least be able to interpret an instruction so as to obtain an operand, perform an operation with that operand, and obtain a new instruction.

The power of a digital computer is much greater if it can alter its sequence in accordance with intermediate results in the solution of a problem. The special instructions used

TABLE I

Man	Man and Desk Calculator
1. Outline table X 17.5X 17.5X + 38.3 1 2 3 . . .	1. Outline table X 17.5X + 38.3 1 2 3 . . .
2. Write down multiplier (17.5)	2. Enter multiplier (17.5) in keyboard. Multiplier remains in computer until cleared out.
3. Write down multiplicand (X)	3. Enter one multiplicand in keyboard (X).
4. Use pencil, paper, and memorized tables to write down product.	4. Push "multiply" key. This initiates process that results in product being displayed in machine register.
5. Write down 38.3.	5. Enter 38.3 in keyboard.
6. Use pencil, paper, and memorized tables to write sum of product and 38.3	6. Push "Add" key. This causes addition to be performed and sum displayed in machine register.
7. Enter sum in table and return to step 2.	7. Enter sum in table and return to step 3.

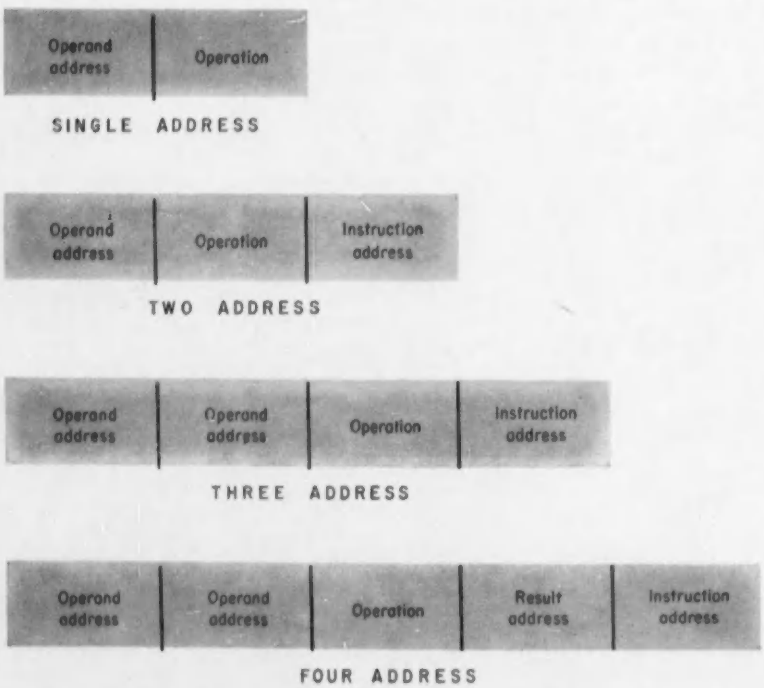


FIG. 1. Typical structures for programming instructions for digital computers.

for this purpose are known as decision, jump, or conditional transfers. In these cases the next instruction address depends upon some condition that prevails in the computer. For example, the instruction may contain two next instruction addresses instead of one and an operand address; when this instruction is received by the control, the choice of the next instruction address from the two available can be made by the computer based on the sign of a number in the arithmetic element at that time.

The programmer's job is to detail all these instructions and thus construct a program defining for the computer the exact sequence of ordinary and decision instructions to be followed to solve a problem. Once the program is entered in the machine by punched tape, magnetic tape, cards, or other means, the computer carries out the entire sequence of operations without further action by the programmer. The power and capability of a digital computer is measured by the speed with which it performs these tasks.

INSTRUCTION STRUCTURE

The instructions previously outlined represent a minimum case. As mentioned, at least an operand address, operation to be performed, and the address of the next instruction are required as part of the instruction structure. In the many digital computers that have been designed, there are numerous variations of this structure, and these affect the design of the control.

One of the most common variations is the so-called "single address system" in which only a single address and operation are contained within the instruction word. The address is that of an operand and the operation is to be performed on that operand. The address of the next instruction does not appear, since in single-address machines instructions usually are selected from the storage in sequence. A separate device is used to control this sequential selection. The sequential selection of instructions from storage can be varied by the use of unconditional jumps, where the operand address specifies the next instruction address, or by conditional jumps, where the key is some condition prevailing within the computer. Typical examples of machines using this structure are the IBM 701, 702, 705, Univac, and Datatron.

In two address machines, the instruction consists of two operand addresses and an operation. In this type structure, as in the single-address structure, the address of the

next instruction to be selected is implied and is selected sequentially from storage. The IBM 650 and the ERA 1103 have two-address instructions.

Three-address machines have also been built; here an instruction contains two operand addresses, an operation and the address of the next instruction; or, in some cases, two operand addresses, the operations and the address where the result or third operand is to be placed in the memory. In this last category the same technique described before is employed: the next instruction address is selected sequentially from storage. The NORC and the NCR-303 are three-address machines.

Four-address instructions contain the addresses of both of the operands to be used in an operation, the operation to be performed, an address for the storage of the result and the address of the next instruction. These instructions contain a complete arithmetic operation. It should be pointed out, however, that they are sometimes inefficient. If, for instance, the operation desired is a transfer of a number from storage to the arithmetic element, then only one operand and an operation need be designated. A portion of the instruction structure is wasted in such an operation. The SWAC has a four-address code.

Partial address

As pointed out in an earlier article, on the use of information theory in design of digital computers, it is not always necessary to totally define all information in a computer. This is particularly true within the designation of the address used in the instruction structure. In the design of machines where the total number of digits carried within the machine is limited, such as computers for military or control applications, it may be desired to squeeze several operand addresses into a limited number of digits. In this case, the address of the next instruction can be the address of the operand plus a small number indicated by a few binary digits. The instruction "733, Subtract, 2" (in binary: "1011011.101, code for subtract, 10") is then interpreted to mean that the operand is selected from storage address 733; the operation to be performed is subtraction; and the address of the next instruction is 735 (=733 + 2). This scheme of instruction is generally known as "partial-address" or "floating-reference" addressing. It is generally referred to as a "1 + (1) address system" rather than two-address.

It can be seen by extrapolating this technique that it is possible to build single-address, double-, triple-, or four- or five-address machines, where each of the addresses required within the instruction structure can either be partial or total. The completion of an operation in a serial machine may serve as a reference point, or the last instruction address may serve as a reference point for the next address.

TECHNIQUE OF CONTROL

A good way to explain the technique of control of digital computers is by tracing through the logical design of a simple controlled digital device. A five-flip-flop register that can perform some of the operations done in a digital computer will be used for illustration. It is basically too simple to perform really useful computations. The five flip-flops in the register are designated "P, Q, R, S and T"; they are simple delay flip-flops. Any one of them, Q for instance, has an input denoted by Qj and two outputs denoted by Q and Q', called the normal and complementary outputs. The truth table for this flip-flop is given below:

Qj_n	Q_{n+1}	Q'_{n+1}
1	1	0
0	0	1

This flip-flop has these characteristics: The Q output is the same as the Qj input was the previous digit time, and the Q' output is always the complement of the Q output. The logical equation of this flip-flop is:

$$Q_{n+1} = Qj_n$$

It is assumed that this five-flip-flop register is part of a synchronous computer. This means that in each flip-flop input the clock pulse is "anded" with the logical input quantity. Since this convention is followed, it is unnecessary to mention the clock pulse specifically in the logical expressions for the inputs to flip-flops.

A characteristic of many electronic digital computers is that they time-share equipment; for example, the same group of flip-flops may be used for several different purposes. The register described will be able to perform several operations under the influence of signals from a control. The modes of operation of this five-flip-flop register will be:

1. Maintain contents
2. Circulate contents
3. Count up
4. Reset to zero.

The logical equations for each of these modes of operations are indicated separately, then these are combined, the mode of operation being selected by the control.

First, the five flip-flops can be made to retain their contents unchanged by selecting the output of each flip-flop for its input:

$$\begin{aligned} Pj &= P \\ Qj &= Q \\ Rj &= R \\ Sj &= S \\ Tj &= T \end{aligned}$$

The five flip-flops become a circulating register if the input to each is the normal output of the one preceding and if the input to the first flip-flop is the normal output of the last. In each digit time the contents of one flip-flop is transferred to the next. The logical equations are:

$$\begin{aligned} Pj &= T \\ Qj &= P \\ Rj &= Q \\ Sj &= R \\ Tj &= S \end{aligned}$$

The five flip-flops become a modulo-32 counter if the inputs and outputs are properly interconnected. The counter shall count in straight binary fashion from zero to 31. In the next digit time it shall start again in the configuration zero. P shall be the flip-flop holding the most significant digit and T the flip-flop holding the least significant digit. Table II, showing the successive states of each flip-flop, is just a tabulation of the binary code for all numbers from zero to 31.

The equations of flip-flop inputs are:

$$\begin{aligned} Pj &= (TSRQ)P' + (TSRQ)'P \\ Qj &= (TSR)Q' + (TSR)'Q \\ Rj &= (TS)R' + (TS)'R \\ Sj &= TS' + T'S \\ Tj &= T' \end{aligned}$$

This register may be reset to the configuration zero simply by withholding all inputs for one digit time.

Controlling the register

Thus far, the logic that will permit this register to behave in any one of the four different modes has been given, but it has not been shown how to make it behave in a specific one of these ways. This is where the concept of control enters. For example, four control lines—A, B, C, and D— are available; the first line is used to cause the register to maintain its contents, the second to make it circulate, the third to make it count, and the fourth to reset it to zero.

If the quantity A is "anded" with the five flip-flop inputs that cause the register to maintain its state, the state will be maintained only when the signal A is present. If B is "anded" to the inputs that cause it to circulate, the register will circulate only when the input B is available. If all of the five flip-flop inputs that make the register count are "anded" with C, the register will count only when the signal C is present. Here the signal D is not required; for the absence of signals A, B and C will result in no inputs to the flip-flops and

	P	Q	R	S	T
0	0	0	0	0	0
1	0	0	0	0	1
2	0	0	0	1	0
3	0	0	0	1	1
4	0	0	1	0	0
5	0	0	1	0	1
6	0	0	1	1	0
7	0	0	1	1	1
8	0	1	0	0	0
9	0	1	0	0	1
10	0	1	0	1	0
11	0	1	0	1	1
12	0	1	1	0	0
13	0	1	1	0	1
14	0	1	1	1	0
15	0	1	1	1	1
16	1	0	0	0	0
17	1	0	0	0	1
18	1	0	0	1	0
19	1	0	0	1	1
20	1	0	1	0	0
21	1	0	1	0	1
22	1	0	1	1	0
23	1	0	1	1	1
24	1	1	0	0	0
25	1	1	0	0	1
26	1	1	0	1	0
27	1	1	0	1	1
28	1	1	1	0	0
29	1	1	1	0	1
30	1	1	1	1	0
31	1	1	1	1	1

TABLE II

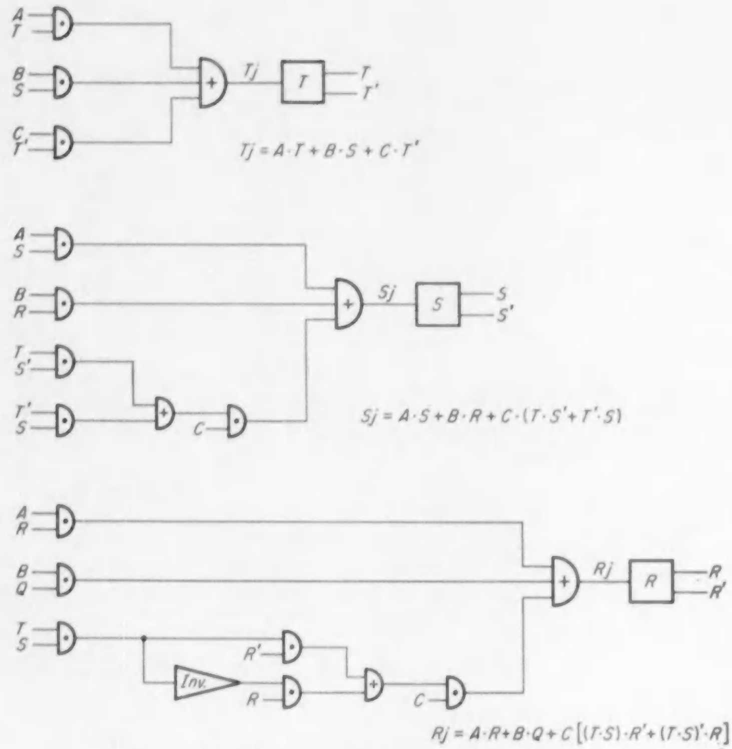


FIG. 2. Schematic diagram of the control gating for three simplest stages of a four-mode, five-flip-flop register.

the flip-flops will thus reset to zero.

The functions of the flip-flops in this five-flip-flop register can now be combined to time-share this register in the four modes described. The terms in the input used for maintaining contents may be added to those used for shifting and may be added to those used to make the register count. (Since not more than one of the control lines A, B, C, D is energized at any time, the four modes do not interfere.) The resulting logical equations for the inputs to these time-shared flip-flops are then:

$$Pj = AP + BT + C[(TSRQ)P' + (TSRQ)'P]$$
$$Qj = AQ + BP + C[(TSR)Q' + (TSR)'Q]$$
$$Rj = AR + BQ + C[(TS)R' + (TS)'R]$$
$$Sj = AS + BR + C[TS' + T'S]$$
$$Tj = AT + BS + CT'$$

In Figure 2 the inputs to the flip-flops in the three simplest cases are indicated schematically. This illustrates clearly why it is very convenient to describe the logic of a computer in the terms of Boolean algebra rather than to indicate this logic by means of schematic diagrams.

In this first figure, gates are cascaded. Considering each "and" gate, inverter, and "or" gate a level of gating, the expression for *Rj* contains six levels of gating; that is, in the input to *Rj*, the output of flip-flop *S* must travel through six gates before it reaches the input to *R* (and, inverter, and, or, and, or). There may be practical considerations which make it inadvisable to have as many as six levels of gating, and in this case, the formal techniques of Boolean algebra make it possible to reduce the number of levels of gating to five or four or three or two. For example, the input to flip-flop *R* expressed in terms of two levels of gating is:

$$Rj = AR + BQ + CTSR' + CT'R + CS'R$$

This is illustrated in Figure 3.

Determination of the logical equations that will permit a five-flip-flop register to behave in a variety of ways according to the kind of control signals it receives has been demonstrated. Now, where do the control signals originate? They may be obtained by techniques similar to that described in designing the five-flip-flop register. For example, A, *B*, and C may themselves be flip-flops that are turned on or off by signals from other portions of the machine. The inputs to flip-flops A, *B*, and C may come from storage where, for instance, they may be recorded in three separate channels on a magnetic drum. The information on the drum, then, is the stored program for our primitive computer.

Despite the simplicity of this device, it is possible to conceive of practical applications for it. A situation requiring the sampling of the frequency of a pulse train could be such an example. The control would establish the counting mode of the flip-flops for a fixed interval, thus giving a measure of the pulse rate of the input pulses. The shifting mode would then allow a serial readout of this number, or the holding mode would allow static inspection of the number. Then the flip-flops could be cleared for another sample.

CONTROL ELEMENT MECHANIZATION

The techniques illustrated above are those used in the design and mechanization of digital computer control elements. Actual computer controls are too complex to be detailed here; however, these elements may be readily understood from an outline description of a control and the foregoing techniques.

Figure 4 is a block diagram of a possible control for a serial computer using a two-address instruction structure and serial storage. The sequence to be performed by this control is: first, to cause storage to locate the operand desired; second, to cause the operation desired to be performed upon that operand; third, to cause storage to select and transfer the next instruction to the control; and then, to repeat this sequence.

Assume that an instruction has been transferred from storage to the in-

struction register. The first step of the sequence, as controlled by the control counter, is to transfer the operand address information through a series of gates to an address register. Here this address is compared by a coincidence detector with the current address of the serial store. When coincidence between the desired and current address is detected, a gate is opened, allowing the selected number to pass from storage to the arithmetic element. This gate is controlled by the coincidence detector and the second state of the control counter.

Operation decoding

The operation desired is decoded by a diode matrix as shown in the right-hand portion of the diagram. The matrix inputs are the coded register information; the output is the activation of one of a number of gates represented by the binary information. This decoding matrix output gate directs the coincidence detector output pulse to the arithmetic element. This pulse activates subcontrols, causing one of the processes of addition, subtraction, etc., to be initiated. The completion of the operation causes the third step in the control counter to be activated. The third step is the transfer of the next instruction address from the instruction register to the address register. Again, comparison between the current and the desired address is detected by the coincidence detector. When coincidence occurs, the current word in the serial memory is transferred through a gate to the instruction register. This gate is controlled by the fourth step in the control counter and the coincidence detector. The new instruction has been introduced into the instruction register and the entire sequence is repeated.

Conditional jumps

If the desired operation is a conditional jump, then the operation decoding matrix is activated immediately after transfer of the instruction to the instruction register. The operation pulse samples some condition, such as the sign of the number in the arithmetic element, and then causes either the normal next instruction address or the operand address to be transferred to the address register. Then, as previously described, this information would cause selection of the next instruction.

In some computers the choice of a conditional address is limited to the specified next instruction address or to a simple modification of this address, such as the addition of one. Either the normal address or that address plus one is selected, dependent upon the condition tested.

Time Sharing

As mentioned, the output of the decoding matrix is a pulse on one of a number of lines going to the arithmetic element to activated sub-sequences controlling the actual arithmetic processes. As digital computer designs improve, it becomes increasingly more difficult to draw a dividing line between the control operation and the sub-sequence control of the arithmetic element. The sub-sequence control generally is a counting sequence with the states of the counting device controlling the various gates of the arithmetic element. The first step of the control element sequence is to transfer the operand address to the address register; therefore, this portion of the instruction register need not be used throughout the remainder of the control sequence. In many digital computer designs these same elements are used for the sub-sequence control of the arithmetic element. This time-sharing is particularly important where minimization is important.

Other instruction structures

If the block diagram were drawn for a single (rather than a two-address) control, the next instruction address would not be derived from the instruction register, since this register would contain only the operand address and the operation. The next instruction address would be contained in a separate counter. The single-address sequence would be the same as previously described, except that the next instruction address would be transferred from this separate counter to the address register. The number contained in the counter would then

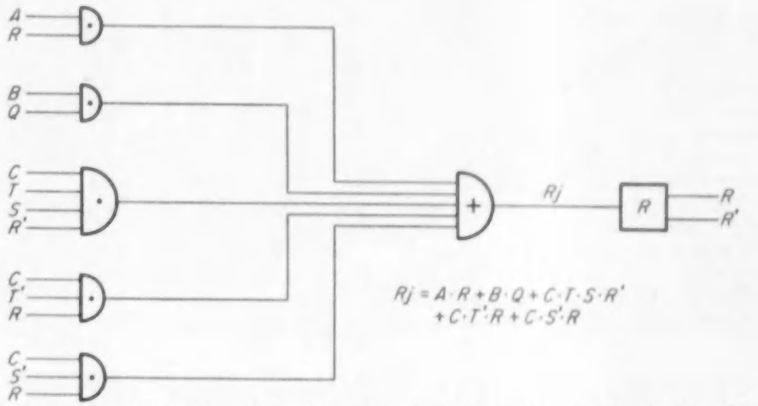


FIG. 3. A two-level gating scheme to replace the six-level gating for Rj of Figure 2.

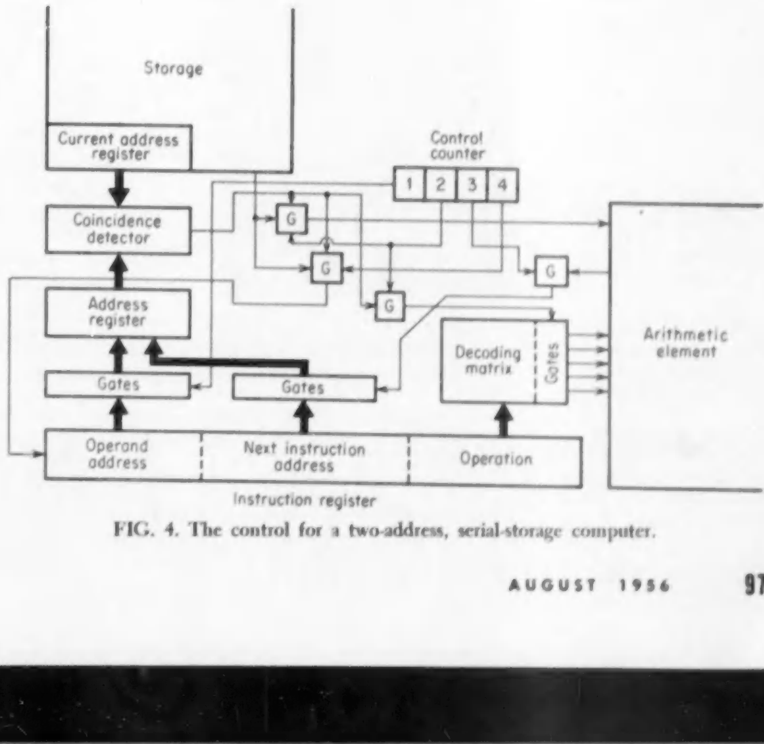


FIG. 4. The control for a two-address, serial-storage computer.

be increased by one to establish the successive address.

Block diagrams for either a three- or four-address machine would vary in the instruction-register length. The sequence performed necessarily would be longer; first, the transfer of the first operand; second, the transfer of the second operand and the activation of the operation decoding; third, the transfer of the address of the result if a four-address machine, or of the next instruction if a three-address structure. These control elements all operate in basically the same manner, although the variations in instruction structures cause differences in the number of steps in the control sequence.

In a 1 + (1) control element the sequence remains as described for two-address except that the next instruction address is generated as the sum of the operand address and the next instruction partial address.

Other programming techniques

In the examples used, serial storage has been assumed where storage locations were selected by comparison with a current-address register. If the storage element is a random-access store, then the coincidence detection is not required. The transfer of address information from the instruction register to the address register causes activation of the storage selection circuits and nearly immediate readout of the stored information. Since the time required for selection of information from storage is fixed, the operation initiation in the arithmetic element takes place immediately. The basic operation of the control in either a parallel or serial computer is the same.

In some digital computers the sequence of instructions is not stored in the internal storage of the computer, but is defined by a separate sequencing device. For instance, the sequence may be defined by a diode matrix. The input lines of the matrix are activated sequentially by a commutating device, such as a counter. The decoded matrix output is a large number of wires that can act as the computer control. If a particular address is desired from storage, the first wire would go directly to the proper storage selection circuits and the second to the arithmetic element to activate a particular operation subsequence. By wiring these matrix output lines with suitable isolating diodes to the other elements of the computer, control is accomplished.

This type of wired-in control does not suffer from possible loss of program due to momentary power failure and, consequently, is often used in control applications where the problem is fixed and reliability is of the utmost importance. General-purpose digital computers, however, rarely use this type of control since it is difficult to modify the program. In some cases, where a digital computer is to be used for a limited number of problems, complete controls in the form of wired matrices are plugged in to provide the instruction sequence for this limited number of problems.

Micro-programming

Micro-programming is a technique sometimes utilized in the design of digital computers. Here the arithmetic and control sub-sequence are actually a part of the instruction sequence. Each detail of the control of the gates and transfer paths within the computer is controlled by the program sequence. Since all these functions are directly under the control of the programmer, it is possible to achieve extreme flexibility in the operational characteristics of the computer. The program or instruction sequence necessarily must be extremely detailed, since the programmer is, in essence, designing the characteristics of the machine that he is to use. This technique is used where a minimum of equipment is required and programming effort is not of concern.

In examples of controls, addresses referred to storage; however, it should be noted that input and output equipment, which are integral parts of the computing system, can also be specified by address. The general remarks concerning address reference to storage also relate to address reference to the input or output.

Even though the detailed mechanization of controls varies greatly from computer to computer, the fundamental purpose of the control remains the same; namely, that of selecting instructions to be performed, interpreting these instructions, and causing the other elements of the computer to carry out the functions required for problem solution.

HOWARD L. ENGEL

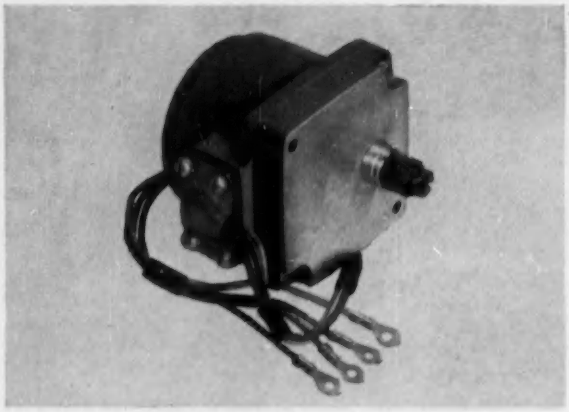
Dr. Engel, a member of the senior staff of The Ramo-Wooldridge Corp., is in charge of systems analysis and logical design of general-purpose computers for military systems applications. He received a BS from Carnegie Tech in 1944 and then spent two years in the Navy. A year at Northrop Aircraft followed, and in 1948 he received an MS in aeronautics from Cal Tech. In 1950, after earning a PhD in engineering mechanics from Stanford University, he joined Hughes Aircraft to do computer systems analysis and logical design and to work on business-data handling systems. He came to Ramo-Wooldridge in 1954.

ELWOOD E. BOLLES

As associate head of the Digital Control Dept. of The Ramo-Wooldridge Corp.'s Computer Systems Div., Mr. Bolles shares responsibilty for development of digital computing systems for military real-time control problems. He received a BS in EE from the University of Washington, Seattle, in 1946, and an MS from the University of California in 1948. After a year in Cal U.'s digital computer development program, he went to Hughes Aircraft, where for five years he did work in the development and flight-testing of airborne digital computing systems. He joined the staff of Ramo-Wooldridge in 1954.

ElectroniK Null Indicator

Modern successor to the galvanometer, this completely electronic in-



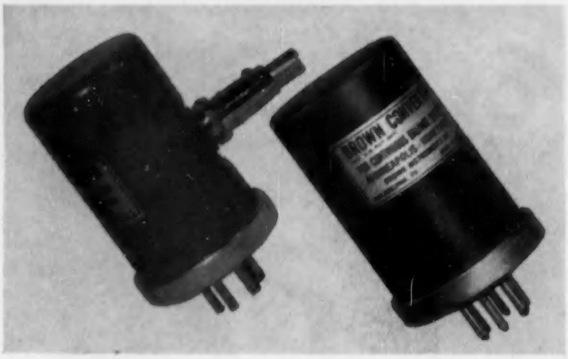
Two-phase reversible motors

Ideal for use in servomechanisms, computers, null circuits. High torque. Fully enclosed. Self-lubricating. Many variations in pinion, shaft, lead wires, and construction materials available for special requirements.

Specifications

No-load speed—rpm	27	54	162	333	1620
Rated torque—in.oz.	30	15	5	4	5
Max. torque—in.oz.	85	43	19	11	9
rpm for max. power	15	31	92	190	900

Reference data: Instrumentation Data Sheet 10.20-2.
Prices from $42.00 (lower on quantity orders).



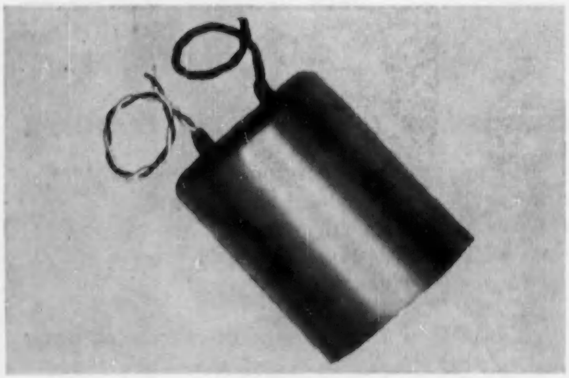
Converters

Convert d-c signals as small as 10^{-8} volt to a-c. SPDT switching action. Sensitive, stable performance . . . ideal for computers, servomechanisms, balancing circuits. Numerous special features can be provided for special needs.

Available in these ratings

Nominal frequency, cps	25	40	60	400
Synchronous range, cps	23-28	36-44	45-66	360-440
Driving coil power	6.3 volts, 60 ma			18 volts, 94 ma.

Reference data: Instrumentation Data Sheets 10.20-1 and 10.20-5.
Prices from $36.00 (even more favorable for quantity purchases).



Input transformers

Handle low-frequency a-c, or chopper-modulated d-c signals from .0005 to 200 millivolts, such as are generated by thermocouples or other transducers. Designed with highly efficient shielding.

Choose from three models		355567-1	356326	355567-2
Primary (center-tapped)	turns (½ primary)	600	1,094	3,400
	Resistance (approx.)	30 ohms	450 ohms	750 ohms
	60 cps impedance	1,300 ohms	7,500 ohms	50,000 ohms
	Impedance, full pri.	5,200 ohms	30,000 ohms	200,000 ohms
Secondary	turns	9,600	17,500	12,000
	Resistance (approx.)	2,500 ohms	5,800 ohms	3,400 ohms
	Capacity to tune to 60 cycles	.015 mfd.	.001 mfd.	.003 mfd.
Weight		5.7 oz.	7.1 oz.	6 oz.

Prices from $21.00 (even more favorable on quantity purchases).

Amplifiers

As a basic link in the servo loop, the Brown amplifier converts a d-c input signal to ac, and amplifies the signal sufficiently to drive a two-phase balancing motor. Readily adaptable to various measuring, balancing, and positioning applications.

Select from these basic models

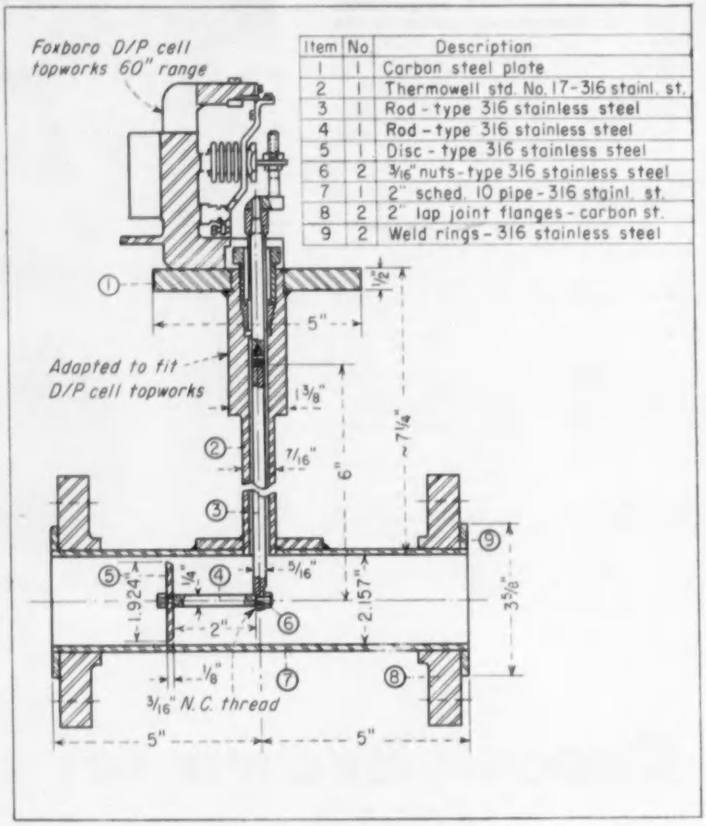
Gain	Sensitivity (Microvolts)	Nominal Input Impedance (Ohms)
10^6	4.0	400, 2200, 50,000*
4×10^6	1.0	400, 7000
12×10^6	0.4	400, 2200, 7,000
40×10^6	0.1	2200

*Special for high impedance sources.
Prices from $98.50 (even more favorable prices on quantity orders).
Reference data: Instrumentation Data Sheets 10.20-3 and 10.20-4.

IDEAS AT WORK

THE PROBLEM: A flow meter able to operate on thick slurries and non-Newtonian fluids such as cellulose acetate dope was needed. This meter had to have a standard pneumatic output and had to be unaffected by the metered liquid.

THE SOLUTION: A basic flow-sensing device was originated by the company. The diagram at the right reveals that it consists of a disc suspended inside the center of a straight pipe section by a force balance mechanism.



Item	No.	Description
1	1	Carbon steel plate
2	1	Thermowell std. No. 17-316 stainl. st.
3	1	Rod - type 316 stainless steel
4	1	Rod - type 316 stainless steel
5	1	Disc - type 316 stainless steel
6	2	3/16" nuts - type 316 stainless steel
7	1	2" sched. 10 pipe - 316 stainl. st.
8	2	2" lap joint flanges - carbon st.
9	2	Weld rings - 316 stainless steel

Drag Disc Design Copes with Tough Flows

G. A. MARTIN and D. DERUITER
Canadian Chemical Co., Ltd.

In February 1954 Canadian Chemical's Process Control group got a "request for service" from the Preparation Dept. of the Yarn area, asking for a way to continuously meter the flow of acetate into its dope filters. A survey of commercially available flow meters revealed no unit suitable for handling this viscous, thixotropic liquid. Hence the group decided to try to design a meter using, as far as possible, parts from available units.

The basic plan was to suspend a carefully sized metal disc inside the pipe-flowing liquid and then measure the drag force through a lever and force-balance mechanism. The first experimental model incorporated the force-balance unit from a Foxboro model 3A d/p cell. This meter was to be inserted in the pipe using a flange stub; later this was changed to a short, flanged spool piece, which permits much closer tolerances.

Preliminary tests on the prototype were very satisfactory: output was stable and followed flow variations closely. But at this stage an accurate calibration was not possible, due to the combination of an untried meter and thixotropic fluid. However, a composite "factor" was worked out in field trials and proved satisfactory in the installation.

More applications

A second application for the "drag disc" meter was measuring a stream of weak acetic acid in the Cellulose Acetate area. The new meter replaced a venturi whose piezometer taps were constantly plugging with fine cellulose and acetate particles. It was first placed in series with the venturi and the field tests were made to calibrate it. These tests also indicated that the calculations for disc size were in error.

The Petrochemical Area provided the third and fourth applications for the drag disc meter: handling an organic liquid and a granular catalyst slurry under high pressure (removing an elaborate, uncertain purging system for the former venturi taps). In the high-pressure measurement, however, the original meter configuration proved impractical for the small, 1-in. pipe. This problem was solved by extending the disc support upstream from the force-balance rod entry point to avoid flow interference in the small entry way. This modification remains.

A fifth application also arose in the Petrochemical Area—measuring a hot, saturated solution of pentaerythritol which tended to crystallize in orifice pressure taps and required a cumbersome hot purge.

Calibration technique

A method was developed for shop-calibrating the drag disc meter to do away with the weigh barrel procedure used in the plant. The fully assembled meter is now clamped in a vise and the center of the spool piece is lined up with a special pulley and

bracket. A thin wire is hooked on the center of the disc and laid over the pulley. Weights equaling the calculated drag force (in this case 1 lb and 13 oz) are attached to the wire, and output pressure of the transmitter is adjusted to 15 psi. After checking the zero point and possibly readjusting maximum output pressure, the calibration is completed.

Coincidental with calibration was development of a formal method of calculating the meter range. The procedure, with a sample calculation, is shown on the opposite page.

Results to date show the calculations agree well with experimental results and may be relied upon at high Reynolds numbers. However, the useful limits of the Beta ratio have not yet been determined as a function of Reynolds number, and low ratios at low Reynolds numbers can be avoided by using smaller pipes.

CALCULATING THE DRAG FLOW METER

1. Developing Its Flow Equation

The flow through an annular aperture can be described by the well-known Rotameter equation:

$$W = 3600 A_w C \left(\frac{2g v_f (P_f - P_w) P_w}{A_f} \right)^{\frac{1}{2}} \tag{1}$$

where: W = mass flow rate—lb/hr
A_w = annular area of aperture—sq ft
A_f = cross-sectional area of float—sq ft
v_f = volume of float—cu ft
P_f = density of float—lb/cu ft
P_w = density of fluid—lb/cu ft
g = gravitational constant—32.17 ft/sec²
C = discharge coefficient

In this equation the drag force is represented by the term: $v_f(p_f - p_w)$

Introducing: F_d = total drag force—lb
D = diameter of meter run—in.
d = diameter of drag disc—in.
$\beta = d/D$
γ = specific gravity of fluid

One can write:

$$v_f(P_f - P_w) = F_d$$

$$\frac{A_w}{\sqrt{A_f}} = \frac{\frac{\pi}{4 \times 144} D^2(1 - \beta^2)}{\sqrt{\frac{\pi}{4 \times 144} D^2\beta^2}} = \frac{D\sqrt{\pi}}{24} \times \frac{1 - \beta^2}{\beta}$$

Thus Equation 1 becomes:

$$W = \frac{3600 D\sqrt{\pi}}{24} \times \frac{1 - \beta^2}{\beta} \times C[2gF_d \times 62.43\gamma]^{1/2} \tag{2}$$

Combining the constants gives the following flow equation for the drag disc flowmeter:

$$\frac{W}{\sqrt{\gamma}} = 16850 C D \frac{1 - \beta^2}{\beta} \sqrt{F_d} \tag{3}$$

The discharge coefficient can be considered independent of the Reynolds Number (Re) in the annular aperture between the pipe wall and the disc for any value of Re > Re_{min}.

$$Re = \frac{4W}{L_p \mu} \tag{4}$$

where: L_p = wetted perimeter—ft
μ = absolute viscosity of fluid—lb/(ft)(hr)

Equation 4 may be written:

$$Re = \frac{4W}{\frac{\pi D}{12}(1 + \beta)\mu} = \frac{15.28W}{\mu D(1 + \beta)} \tag{5}$$

Thus C is constant for:

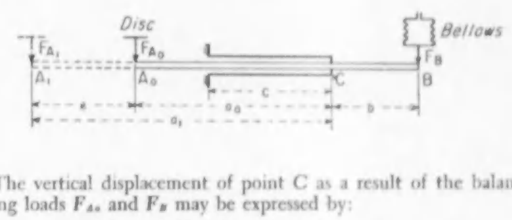
$$\frac{15.28W}{\mu D(1 + \beta)} > Re_{min} \tag{6}$$

Hence, in order to operate in the region where C is constant, the ratio β is limited by the following expression:

$$\beta < \frac{15.28}{\mu D Re_{min}} - 1 \tag{7}$$

2. Evaluating Effect of Lever Extension

Since the lever of the force balance mechanism that was used in the Drag Disc Flowmeter had to be extended in order to suit the design, an expression had to be derived to relate the force on the extended lever to the force on the original lever for the same output pressure of the transmitter.
The lever arrangement is shown schematically below:



The vertical displacement of point C as a result of the balancing loads F_{Ao} and F_B may be expressed by:

$$y_c = \frac{(F_{Ao} + F_B)c^3}{3EI} + \frac{(F_B b - F_{Ao} a_o)c^2}{2EI} \tag{8}$$

where: E = Young's modulus for flexure tube
I = moment of inertia of cross-section of flexure tube

Now it can be assumed with reasonable accuracy that: $y_c \sim 0$.
Hence:

$$\frac{(F_{Ao} + F_B)c^3}{3EI} + \frac{(F_B b - F_{Ao} a_o)c^2}{2EI} = 0 \tag{9}$$

or:

$$F_{Ao} = F_B \frac{3b + 2c}{3a_o - 2c} \tag{10}$$

Similarly:

or:

$$F_{A1} = F_B \frac{3b + 2c}{3a_1 - 2c} \tag{11}$$

Dividing 11 by 10 gives:

$$\frac{F_{A1}}{F_{Ao}} = \frac{3a_o - 2c}{3a_1 - 2c} \tag{12}$$

For the force balance mechanism that was used in the Drag Disc Flowmeter the dimensions were:

$$a_o = 3.1875 \text{ in.}$$
$$c = 1.609 \text{ in.}$$

Further, let $a_1 = a_o + e$

Where: e = extension length of lever—in.

Equation 12 now becomes:

$$F_{A1} = F_{Ao} \frac{2.115}{e + 2.115} \tag{13}$$

3. Determining the Bellows Range

The following table presents the experimentally determined range of the force F_{Ao} to produce an output pressure of 3-15 psi for the different bellows ranges of the Foxboro Model 3A d/p cell, using the 100-in. flexure tube.

Range No.	Bellows Range in inch H_2O	Minimum Force in lb for 15 psi	Maximum Force in lb for 15 psi
A	0- 60 to 0- 79	2.2	9.0
B	0- 80 to 0-129	5.2	10.7
C	0-130 to 0-249		
D	0-250 to 0-399	13.4	30.2

From this table the drag force range of a series of combinations of bellows types and level extensions can be calculated with the aid of Equation 13, where F_{d1} represents the drag force F_d. Those force ranges are plotted in Figure 3 for extension lengths varying from 1 in. to 10 in.

HERE'S A SAMPLE CALCULATION

1. Presenting the Flow Problem

A Drag Disc Flowmeter has to be designed for a flow of pentaerythritol.

Flowrate: 30,000 lb/hr
Meter run: 2 in. SCH.108 (ID = 2.157 in.)
Sp. gr. at flow temp: 1.03

2. Determining Extension Length, Bellows Range, & Disc Size

Equation 3: $$\frac{W}{\sqrt{\gamma}} = 16850CD\frac{1-\beta^2}{\beta}\sqrt{F_d}$$

Experiments have indicated that in the range of Reynolds numbers being used, the discharge coefficient C = constant = 0.565.

Thus: $$\frac{30{,}000}{\sqrt{1.03}} = 16850 \times 0.565 \times 2.157\,\frac{1-\beta^2}{\beta}\sqrt{F_d}$$

and: $$1.44 = \frac{1-\beta^2}{\beta}\sqrt{F_d}$$

A disc size must be selected so that the required force range may be determined. Several disc sizes may have to be tried to arrive at a satisfactory extension length. The minimum length is determined by the physical limitations of the design and is given by:

$$e_{min} = \tfrac{1}{2}D + 1 \text{ in.}$$

Due to design considerations, the extension length must be kept as small as possible. The disc size should preferably be between 0.5D and 0.8D.

We try: $$\beta = 0.6$$

Then: $$\frac{1-\beta^2}{\beta} = 1.067$$

and: $$\sqrt{F_d} = \frac{1.44}{1.067} = 1.35$$

In order to have a good measuring range, a bellows range A and an extension length e = 4 in., are selected from Figure 3. This allows the maximum load to be varied from

0.87/1.35 x 100% to 1.76/1.35 x 100%

or 64.5 to 130 percent of the design load. The disc size now becomes: d = 0.6 x 2.157 = 1.294 in., and the drag force for 15 psi transmitter output: $F_d = 1.35^2 = 1.82$ lb or 1 lb and 13 oz.

Simple Wide-Band Impedance Measurements

Here is a simple instrument that can be very useful in finding the effects of loading, resonances, reflections, etc., on the frequency response of transducers or other frequency-sensitive elements that exhibit electrical impedance as a significant parameter.

EDWARD S. SHEPARD SR.
AiResearch Mfg. Co.

The old "three-voltmeter" method is a powerful tool for determining electrical impedance. Because it can give accurate results over a wide frequency range, it is useful for studying those components whose frequency response is reflected in a variation of impedance with frequency change, such as transducers, transformers, and electromechanical actuators. A simple instrumentation now makes the technique very convenient, too. A variable-frequency oscillator and a vacuum-tube voltmeter are the only needed auxiliary equipment.

Impedance measurement is made by comparing the voltage drop across the unknown impedance with the voltage drop across a resistive standard that has been placed in series with the unknown, as in Figure 1A. The constant-current resistor should be about

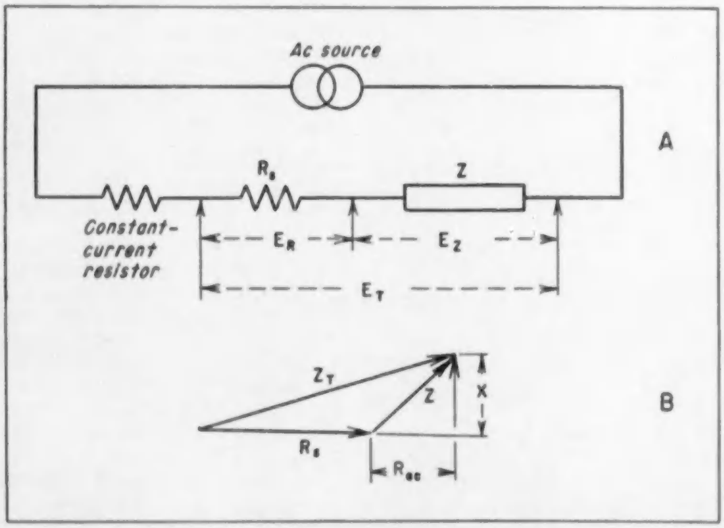


FIG. 1. (A) Series circuit for measuring unknown impedance Z; (B) the resulting impedance diagram.

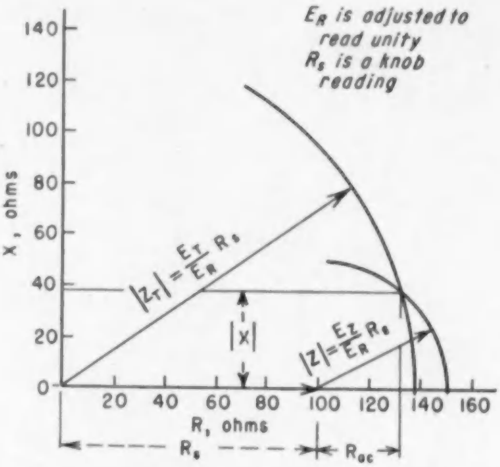


FIG. 2. Construction for obtaining reactance and ac resistance of unknown from measured impedance magnitudes.

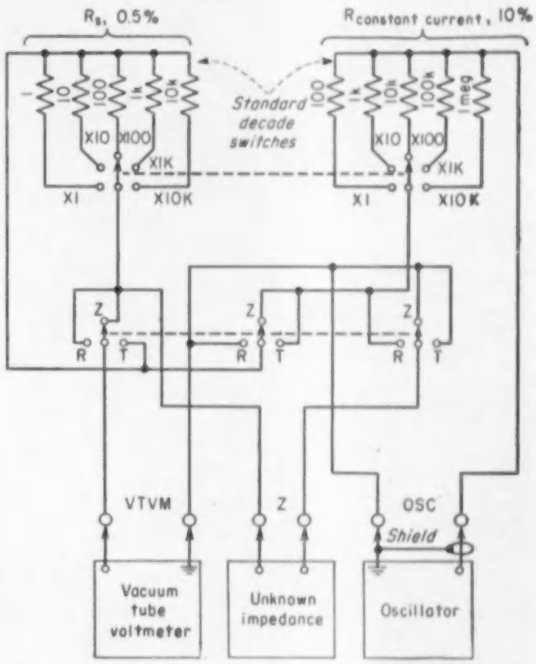


FIG. 3. Circuit of the Impedometer.

100 times the standard resistance. The voltages indicated are proportional to the magnitude of the impedances in the vector diagram of Figure 1B. The impedance triangle can then be constructed graphically, as in Figure 2.

Two selector switches and two resistance decades are all that are needed to build the simple instrument (called an Impedometer) schematized in Figure 3. Its use greatly simplifies the procedure for obtaining the proportional voltages of Figure 1. An audio oscillator of good waveform, preferably with an output impedance of 1,000 ohms or less, is required as a voltage source. A sensitive vacuum-tube voltmeter such as the Ballantine model 300 should be used to measure the voltages.

Measuring procedure

To measure an unknown impedance with the Impedometer, the standard-resistance decade switch is set at the value nearest the estimated value of the unknown. With the "RZT" switch at *R*, the oscillator output is adjusted to give a reading of 1.0, 0.1, or some other power of 10 on the voltmeter. This reading is then interpreted as 100 percent of the standard resistance. Turning the RZT switch to the Z position then gives a voltmeter reading proportional to the unknown impedance. For example, if the voltmeter were set to 1.0 volt in the *R* position with the standard resistance switch set at 100 ohms, and the voltmeter reads 2.38 in the Z position, the unknown impedance is equal to 238 percent of 100, or 238 ohms.

The total impedance can be found similarly. These readings are still only the magnitudes of the impedances. These magnitudes must be plotted as in Figure 2 to find the reactance and ac resistance of the unknown. An arc of radius Z_T constructed about the origin will intersect an arc of radius Z constructed about the end of the zero-angle vector representing the known standard resistance R_s. The intersection of these arcs determines the impedance triangle. The sign of the reactance must be found independently: if a small capacitor in parallel with the unknown lowers its measured impedance, the reactance sign is negative, i. e., the impedance is capacitive.

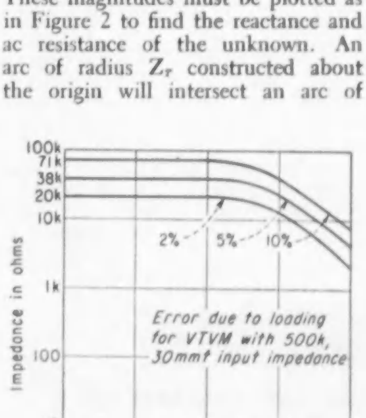


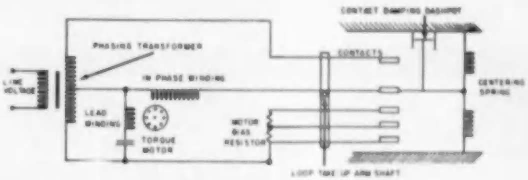
FIG. 4. Accuracy depends on loading effect of voltmeter.

The impedance of an unknown may be displayed dynamically by using a sweeping oscillator as the voltage source and connecting a cathode-ray oscilloscope to the VTVM terminals of the Impedometer. The oscilloscope can be calibrated as above by switching from *R* to *Z*, thus permitting actual impedance values to be read from the screen.

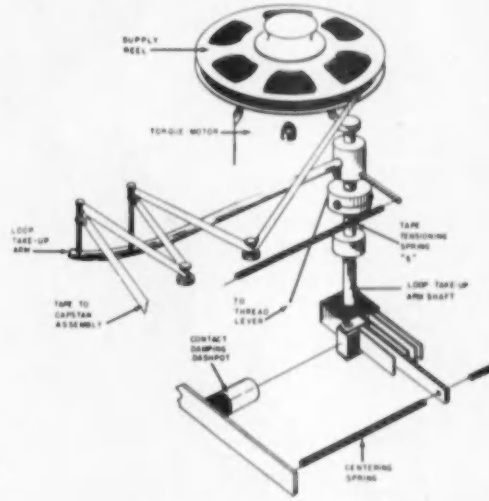
Measurement accuracy is essentially limited by the voltmeter used. Because the impedance measurement is obtained as the ratio of two voltages, the voltmeter should have a logarithmic scale to make the meter error a constant percentage over the range. Linear voltmeters have relatively large percentage errors near the zero end of the scale.

Loading of the Impedometer by the input impedance of the voltmeter also produces some error at high impedance values and at high frequencies, as illustrated by Figure 4.

IDEAS AT WORK



Simple Servos Wind Computer Tape



A properly damped contactor servo assures smooth, trouble-free performance by the tape-storage reels of computer magnetic-tape-transport mechanisms that must start or stop the tape quickly and frequently.

R. M. BRUMBAUGH, Ampex Corp.

Magnetic-tape-transport mechanisms for computers must be able to start and stop the tape very quickly—in the order of a few milliseconds. And what may be even more important, the start and stop characteristics must be consistent from one operation to the next; i.e., the same amount of time and length of tape must be consumed by each start or stop.

To get fast starts and stops, the relatively large inertia of the reels must be isolated from the section of tape near the record and reproduce heads. This low-inertia section can then be accelerated very rapidly provided there is sufficient "free" tape storage between the constantly-running capstan, to which the tape is pinched for driving force, and the reel, which must start and stop very slowly. The mechanism that provides this tape storage must also maintain uniform tension in the tape during running, starting, and stopping. For maximum repeatability of start and stop characteristics response should be smooth.

Electronic servomechanisms offer easy controllability of response, but are quite complex and costly for tape transport mechanisms. A step or "on-off" controller offers maximum reliability and simplicity, but the response usually leaves much to be desired. The system described here combines the best features of both—simplicity, reliability, and smooth response.

A practical solution

The diagram shows the essential details of the servo system for one tape reel. Tape is stored in the loops between the capstan and the reel. Quiescent or static tape tension is established by the tensioning spring. The length of the spring and the position of the spring lever arm are such that the tape tension is almost constant over the full displacement of the loop take-up arm. Quiescent tape tension (3 oz) is balanced by a motor torque determined by the motor bias resistor. The actual system has two such bias torque levels, and enough purposely introduced friction to eliminate hunting and contact bounce over the entire range of reel load.

The control contactor is restrained by the centering springs, and this establishes the neutral position of the loop take-up arm. A sudden supply or demand of tape from the capstan section acts as an input signal to the reel servo, tending to reduce or increase the tape tension. The take-up arm moves with the force unbalance. The contactor, in turn, switches the motor's in-phase winding to the appropriate side of the phasing transformer. Full-power motor torque drives the reel in a direction to restore the loop take-up arm and contactor to neutral by taking tape from, or supplying tape to, the storage loops.

Error-rate response is included by mechanically connecting a small dashpot to the control contactor, as shown in Figure 1. The force supplied by the dashpot is proportional to the rate of displacement of the take-up arm. It acts to close the contactor more quickly if the take-up arm displaces faster, and thus to minimize operating variations due to full or empty reels, different tape speeds, etc.

Easy rewind is a bonus

High-speed tape rewind is also very convenient with this servo. By removing power from one reel servo, the tension-balancing torque is eliminated. The differential in tape tension then causes the other reel to take up the tape at maximum speed. Rewind is stopped by restoring control to the disabled servo. Total rewind time for a standard 2,400-ft, 10-in. reel is less than 2 min.

One question which might be asked: Are contacts reliable and sufficiently long-lived for this application? As it happens, circumstances are more favorable than they might appear. First, ac is used to reduce the problems of metal transfer, pitting, and contact sticking. Second, and possibly more important, when tape is demanded by the capstan at rates greater than about ten starts per second, the servo integrates this motion into an average reel speed. Thus, the contacts make and break less than ten times per second as a worst possible condition.

In actual life tests, under full power to an inductive load, the contacts have made over 60 million cycles with more than 50 percent of the contact material remaining for useful service. At an assumed average of five contact operations per second, this would represent about 3,200 hours as half the life of the contacts.

Easily Standardized Exposure Control

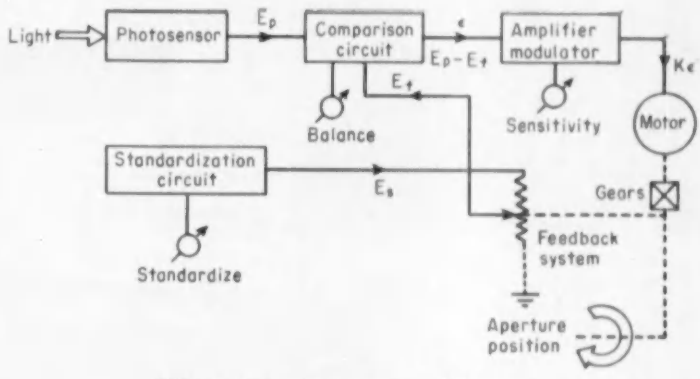


FIG. 1. Automatic exposure control system.

Here's an automatic control system with an especially simple standardization scheme. It can be calibrated on the spot for various film and shutter speeds, and can allow for filters and intentional over- or under-exposures.

DE WITT H. PICKENS*
Tammen & Denison, Inc.

When it is remembered that "one picture is worth a thousand words", the advantage of a photographic instrumentation system over other systems (such as radar) in common use on ballistic test ranges becomes evident. Photographs provide data on target attitude as well as permanent records of the test.

The quality of a film record depends on the camera and lens, atmospheric and light conditions, film type and filters, and the setting of camera parameters by the operator. Most camera parameters, like focus and orientation of the field of view, can be limited by proper choice of the test geometry so that a single initial setting is satisfactory during a given test. But the ambient light conditions that dictate the particular lens aperture setting to be used vary randomly and are at least partly unpredictable. In ballistics range work, in which a target must often be tracked from horizon to horizon through the zenith, the camera iris must be varied throughout its entire range to achieve consistent film exposure.

Automatic iris control

The automatic exposure control system is basically a closed-loop positional servo system. Figure 1 is its functional diagram. Such a positional system is a velocity-type control system with the positional aspects attributable only to the nature of the feedback signal; i.e., if the loop were opened, the system would control output velocity. It follows from this that the positional accuracy of the system is primarily a function of the accuracy and resolution of the feedback system. Response, delay, and stability are functions of the entire servo loop.

The system operates as follows: a photosensor responds to the level of

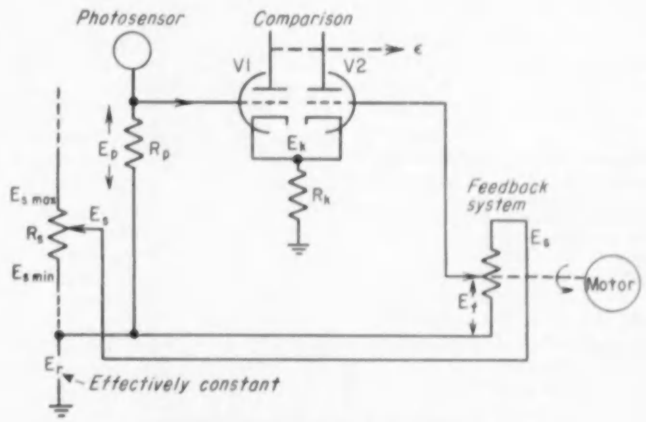


FIG. 2. Standardization circuit and error detector.

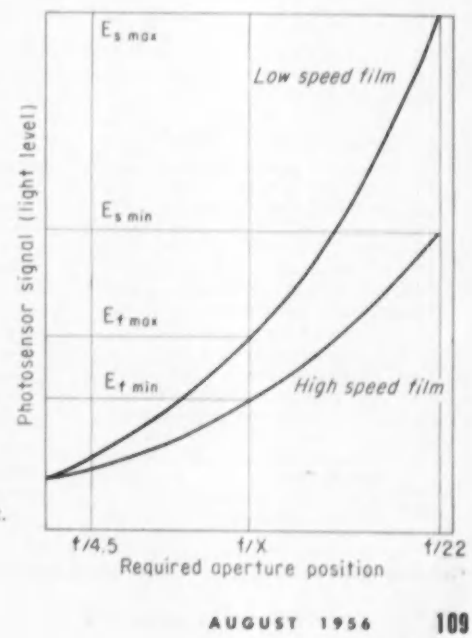


FIG. 3. Characteristics of standardization circuit.

*Formerly with the Chicago Midway Laboratories of the University of Chicago.

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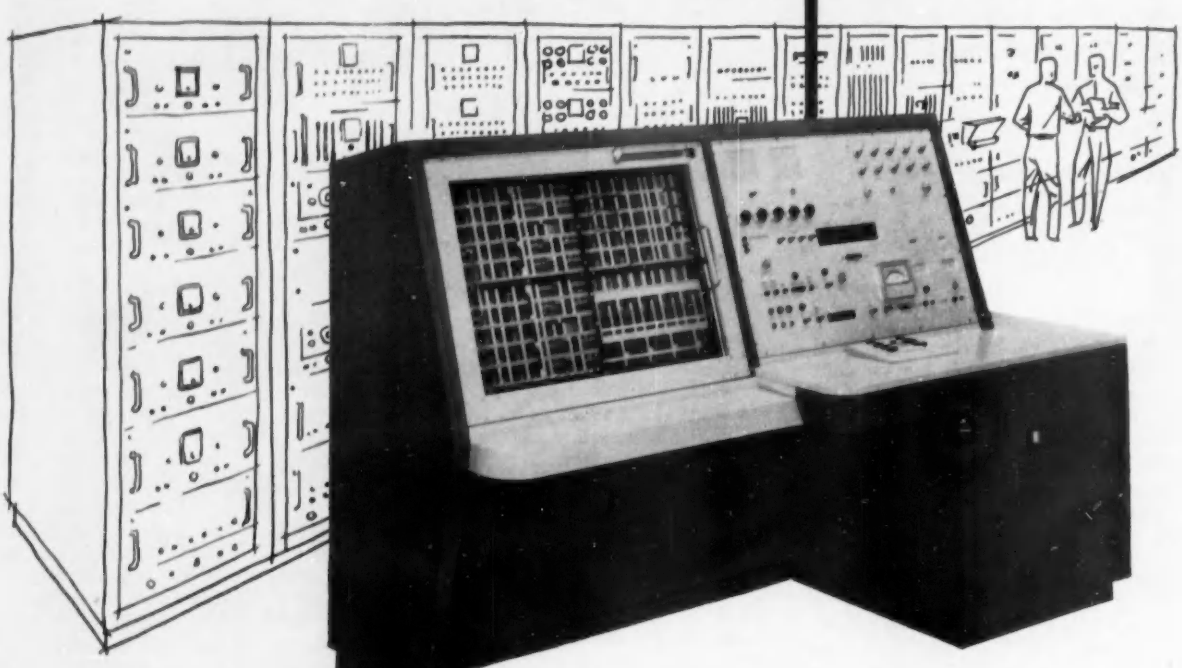

MODEL 1200 console is focal point of 100-amplifier computer, serving (1) to tie together all computing elements, (2) as an input translator to set coefficients, initial conditions, constants from keyboard or punched tape, (3) as output source for analog and digital recorders, (4) as checking device to detect wiring or pot-setting errors, (5) as control point for switching, timing operations, and for indicating circuit amplifier overloads or circuit malfunctions, (6) switching point for all primary power. 3600-terminal patchboard is color-coded for simplified problem patching.

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Specific features include:

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2. Automatic punched tape or card attenuator setting
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4. Built-in static and dynamic problem checking system
5. Built-in 6-channel chart recorder, or electric typewriter with punched tape readin—readout equipment
6. Completely shielded patch cord and patch board system
7. "Human engineered" centralized console design
8. Instantaneous and "stored" overload indication
9. Unitized design for complete flexibility and future expansion
10. .01% accuracy—not only in passive elements, but also featuring the ability to set gains completely through amplifier to better than .01%

These are, of course, but a few of the many advanced-design features that make "Do it with EASE*" more than just a slogan. Complete descriptive and technical data will gladly be sent on request; please address Dept. L8

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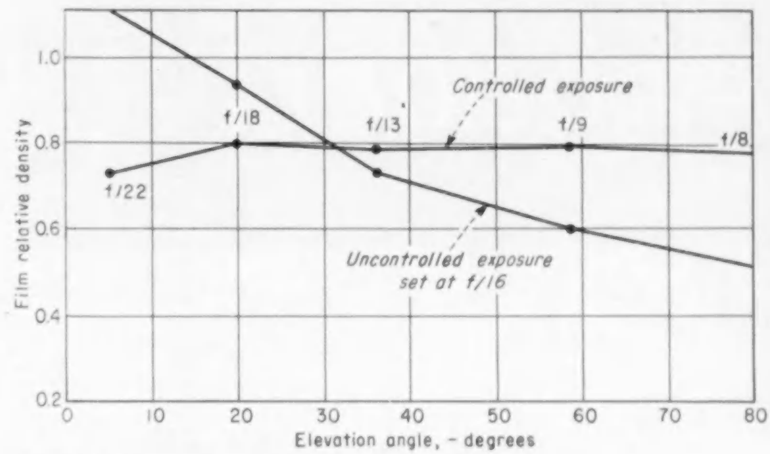


FIG. 4. Relative exposure, controlled and uncontrolled.

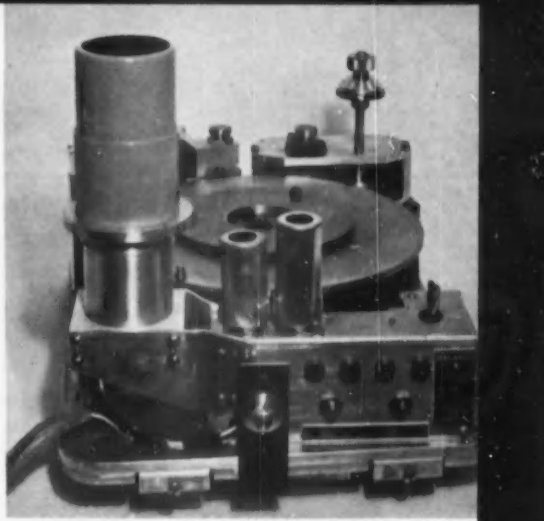


FIG. 5. Servo drive unit, photosensor lens and amplifier in foreground. Control unit is separate, about same size.

ambient light to generate a standardized command signal, E_p, which is amplified and used to drive a servomotor. The motor then drives the aperture control element and at the same time generates a feedback signal, E_f. This feedback signal is compared with the command signal in the comparison circuit and when the difference between these two signals is zero the error signal, ϵ, become zero and the motor stops in the position established by the characteristic of the feedback transducer. When light conditions change so that the command signal is not equal to the feedback signal, an error signal appears and drives the motor to a new position where the error signal again becomes zero.

If the feedback transducer has the correct characteristic, the desired lens aperture results. The feedback characteristic is theoretically square-law, but is actually modified because of nonlinearity in camera iris linkages.

Standardization

The standardization method makes the system useful with a wide range of film types. Figures 2 and 3 illustrate the techniques for providing the system with a relatively simple but accurate means of calibration.

The standardization is effected electrically, Figure 2, and has none of the mechanical shutters or slaved-aperture systems generally found in light-calibrated systems. At no point in the standardization procedure is the photosensor disturbed, either in its aperture or field of view; hence the operating range for the system is limited only by the saturation point of the phototube. Experience with the prototype model has shown that the range of linear operation of the phototube is sufficient to allow use of film ranging from Kodachrome with a film speed of 10 to Shellburst Linagraph with a film speed of 180.

The standardization circuit establishes a variable reference level for the system. The standardizing control varies the point on the feedback potentiometer (and thus the aperture setting) at which the comparison circuit balances the photosensor output for any given light level.

For balance to be effected, both the photosensor and feedback input sections are biased at the same point, E_r. Further, this bias does not shift more than 2 percent as the standardization is varied over its range. The unbalance due to this small variation is not large enough to cause movement of the servomotor in the prototype model.

The curves of Figure 3 are characteristic of the standardizing circuit. For a high-speed film an aperture setting of fx would require a voltage of $E_{f\ min}$ to appear at the fx position on the feedback potentiometer. For a low-speed film this voltage would have to be $E_{f\ max}$ to balance the command signal, E_p, and make the error ϵ, zero.

Standardizing procedure

To standardize the exposure control system, a light-meter reading is taken on a suitable surface to find a correct f-setting for the particular film and exposure time. The aperture is then manually held at this f-stop and, with the camera pointing at the surface, the standardization control is turned until an error signal indicator reads zero. The standardization can then be checked at random, even during a recording mission.

This calibration method requires no highly-trained personnel and no complex equipment other than a light meter which is a standard accessory for cameras. Besides permitting a wide range of films to be used, the method also allows under- or over-exposure, as is sometimes required for special-purpose photography. In this case the system is standardized at a greater or lesser f-number than indicated by the light meter, according to the degree of over- or under-exposure desired. This also allows the use of spectral corrective filters since the filter factors can be inserted by a suitable over-exposure.

Test results

In a performance test, the system was standardized and the theodolite pointed at the darkest point of the sky around sunset, then lowered in elevation to a point on the horizon a few degrees to the left of the sun. The theodolite was lowered at a uniform rate while making one exposure per second.

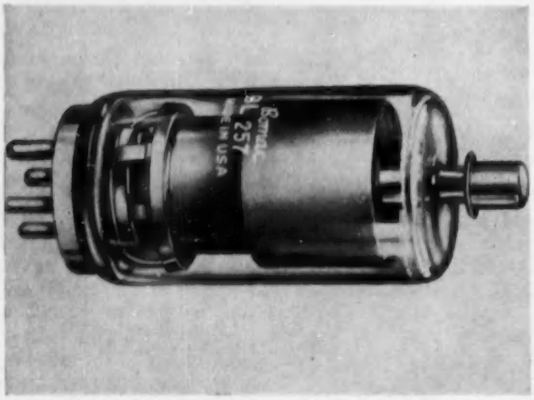
Figure 4 shows the variation in relative film density for super XX film, for both controlled and noncontrolled exposures.

This system was developed at Chicago Midway Laboratories under a joint Department of the Air Force, Air Research & Development Command contract for the Photooptics Branch, Armament Test Equipment Laboratory, Air Force Armament Center, Eglin Air Force Base, Florida.

The author extends a grateful acknowledgment to George F. Warnke, Chicago Midway Laboratories, for his contribution to the design of the servo sections of the system, and to Robert N. Lewis, Richard D. Crenshaw, and Warren P. Harvey, all of Chicago Midway Laboratories, for execution of the field test program.

The development was monitored by the personnel of the Air Force Armament Center, in particular, W. H. Henkel, whose continued guidance and encouragement are gratefully acknowledged.

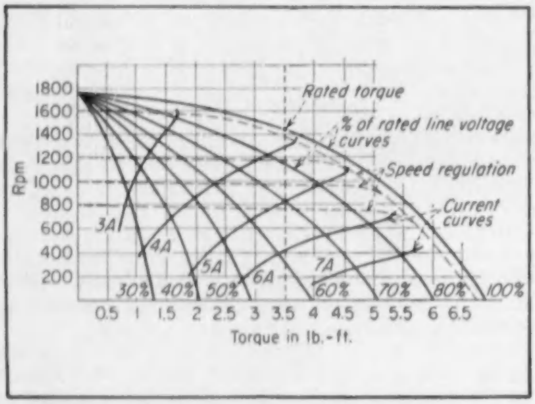
NEW PRODUCTS



HYDROGEN THYRATRON for high impacts.

A new hydrogen thyratron tube, the BL-257, designed for rugged vibration and high impact service, is now available. The tube is rated for 5 g vibration from 60 to 500 cps and 3 g from 500 to 1,200 cps. The tube will also stand a 60 g impact shock in any direction. Electrical ratings are 8.0 kv peak anode voltage, 90 amp peak current and 100 milliamp anode current. It is rated to operate over the temperature range of minus 50 degrees C to plus 90 degrees C and for an altitude of 10,000 ft.—Bonac Laboratories, Inc., Beverly, Mass.

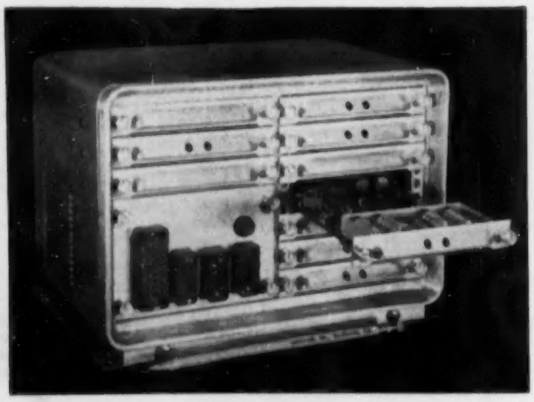
Circle No. 1 on reply card



HIGH TORQUE adjustable drive.

This 400-cycle adjustable-speed drive provides closely regulated infinite adjustability in a range as high as 100:1. Regulated full-load speed exceeds 18,000 rpm. Stepless reduction to speeds of less than 200 rpm may be accomplished without reducing the load torque. The absence of brushes and slip rings reduces radio interference and makes suppressors unnecessary. The stepless control results from manipulation of the negative feedback from a generator connected to the motor shaft. This velocity damping signal is fed to a compact amplifier, where the speed control is accomplished.—WacLine Inc., 35 S. St. Clair St., Dayton 2, Ohio.

Circle No. 2 on reply card



DIGITAL encoder generates 24,000 groups/sec.

A digital encoder designed to accept 0 to 10 volts input levels and generate 24,000 8-bit binary code groups per sec defines the input at an overall accuracy of 1 part in 256. The unit uses etched circuit plug-in cards to ease maintenance and increase operational reliability. The packaged unit weighs only 8 lb and the overall dimensions are 6¾ in. by 9¾ in. by 6¾ in. Miniature connectors, used to provide facilities for interconnection, are located on the front panel for easy accessability.—Radiation, Inc., Melborne, Fla.

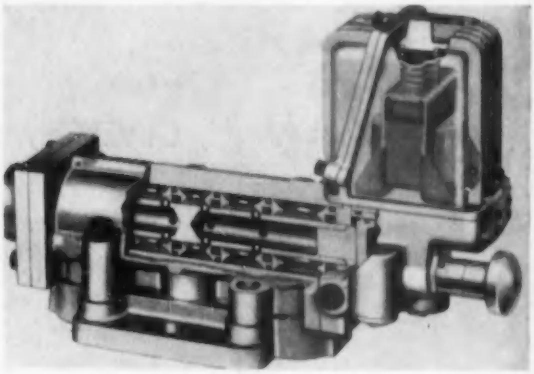
Circle No. 3 on reply card

SOLENOID VALVES have simplified spacers.

These "B"-Type air and hydraulic control valves feature extremely high cycle operation. They are rated at 600 cycles per min for continuous operation on air, at pressures from 40 to 150 psi; and can operate on air at 80 to 100 psi at much higher speeds. Exterior feed-type valves can be used in hydraulic service at pressures up to 250 psi using air for the pilot medium. Interior feed-type valves can be used on oil from 40 to 150 psi at somewhat lower cycling speeds.

The solenoid valves are of pilot-operated design. The short stroke and small force needed by the solenoid means low amperage requirements, simplifying the electrical control circuit.—C. E. Hunt & Sons, Inc., Salem, Ohio.

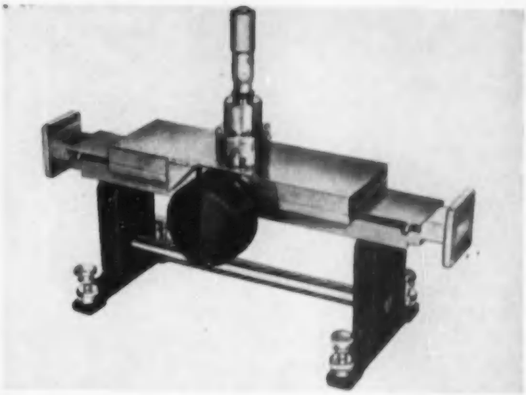
Circle No. 4 on reply card



HIGH POWER variable reactance.

This instrument is used to introduce a standing wave of desired magnitude and phase in a waveguide transmission line. Rated at 300 kw peak power in matched line, the unit will operate directly at any power level up to the breakdown power level of the waveguide. The standing wave ratio in the line can be varied from 1.02 to 2.0 by means of a micrometer adjustment. The residual VSWR is less than 1.02 and the phase of the standing wave is independently variable. The phase scale offers direct reading to 0.5 mm.—Narda Corp., Mineola, N. Y.

Circle No. 5 on reply card



SERVO ERROR analyzed by test stand.

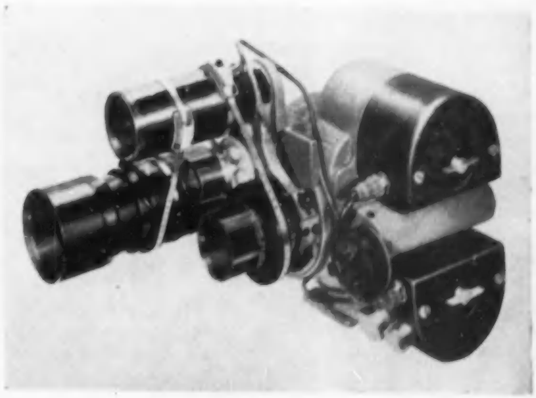
A new servo error analyzer for all types of torque or control transmitters, receivers, and transformers is of the 60-400-cycle variety. Designed primarily as a quality control instrument for laboratory calibration, it is accurate to plus or minus 10 sec in 10-deg steps and provides a stable indication of the fundamental null and the total harmonic null-signal in millivolts. A phase-shift zero indicator is a function of the fundamental frequency with a resolution of 2 sec. Third and higher harmonic signals are attenuated 40 db on both 60- and 400-cycle setups.—Pennsylvania Testing Labs., Doylestown, Pa.

Circle No. 6 on reply card

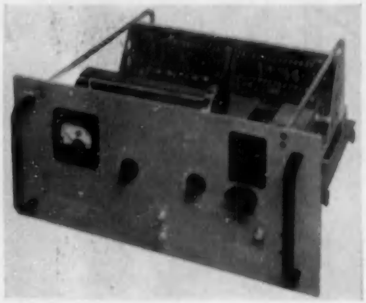
EXPOSURE CONTROL for movie cameras.

A completely automatic exposure control system for motion picture cameras is shown here. Completely self-contained, the entire unit weighs only 3½ lb (including the flashlight cells which drive it). The drive unit weighs only a little over 1 lb and is approximately 4½ in. long and 2 in. in diameter. The unique attachment was designed primarily for 16 mm and 35 mm cameras. The speed of response of the control system can be varied to meet different requirements. Speeds which provide full travel from f2 to f22 in as little as one second can be achieved.—Flight Research, Inc., Richmond, Va.

Circle No. 7 on reply card



RESEARCH, DEVELOPMENT, & TEST EQUIPMENT



SIGNAL SOURCE

New 1 mc signal source is stable to one part in 10 deg. It is tunable over a range of plus or minus 0.5 cps and is capable of a sine wave output of 4 volts rms or a pulse output of 1 volt. The signal source is temperature stabilized to better than 0.01 deg C, and the output impedance of the unit is approximately 250 ohms.—Hycon Eastern, Inc., 75 Cambridge Parkway, Cambridge 42, Mass.

Circle No. 8 on reply card

PRECISION VFO

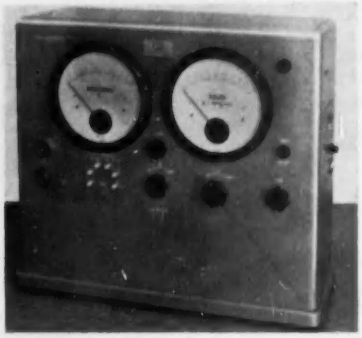
Precision variable frequency oscillator may be used as an exciter or a heterodyne frequency meter. The unit, when used as an exciter, has a frequency range of 2 to 8 mc continuously variable in two bands. It will produce a sinusoidal 3-watt output. When used as a frequency meter the transmitting range is 2 to 30 mc. In addition, when used as a frequency meter, the receiver range is 2 to approximately 100 mc. A high degree of reading and setting accuracy is accomplished by a mechanical counter-dial system which is coupled to a special correction cam to provide a linear calibration curve.—The Technical Material Corp., 700 Fenimore Rd., Mamaroneck, N. Y.

Circle No. 9 on reply card

DIGITAL VOLTMETER

A four-digit digital voltmeter with a one-digit accuracy, automatic calibration, and 0.01 percent stability, will measure voltages in the range of 0.001 to 999.9 scale and 11 megohms on all other scales. Calibration is continuous and automatic, as is polarity and range switching.—Electro Instruments, Inc., 3794 Rosecrans St., San Diego 10, Calif.

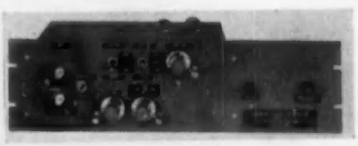
Circle No. 10 on reply card



MEGOHMMETER

New ohmmeter for high resistance measurements covers a range of 20 to 5,000 million megohms in six ranges. The overall accuracy of the instrument is plus or minus 3 percent of the center scale reading. Test voltages are continuously adjustable from 100 to 1,000 volts dc and both grounded and ungrounded test connections are available.—Federal Telephone & Radio Co., 100 Kingland Rd., Clifton, N. J.

Circle No. 11 on reply card



PULSE GENERATOR

High current pulse generator for use in magnetic core systems delivers positive-going rectangular wave current pulses of variable duration, rise-time and amplitude. Basically the unit is a 4-stage unit comprising a multi-vibrator, inverter-amplifier, cathode-follower and current amplifier. The multi-vibrator section permits the selection of any pulse-width from 1 to 40 microsec while the inverter amplifier stage provides a rise time from 0.15 to 1.0 microsec. The overall output amplitude can be varied from 0 to 2 amp.—The Reflectone Corp., Myano Lane, Stamford, Conn.

Circle No. 12 on reply card

AUTOMATIC VTVM

Automatic vacuum-tube volt-ohm meter provides fully automatic range switching, automatic scale indicator lights, and direct reading on an 8½-in. meter. The unit measures ac and dc voltages from 0.1 to 1,500 volts and incorporates complete burnout protection up to 2,000 volts. The resistance measuring scales provide coverage from 0.5 ohms to 1 billion ohms in six ranges.—Leitch Engineering Corp., Manchester, N. H.

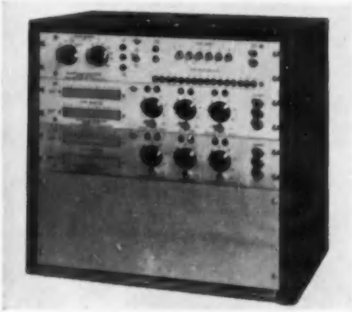
Circle No. 13 on reply card

MICROWAVE ATTENUATORS

Calibrated variable attenuators represent an uninterrupted series for the frequency range of 2,600 to 18,000 megacycles. These attenuators are all of the parallel vane type with dissipative elements of Pyrex vanes and an evaporated nichrome film. A precise dial is provided for accurate measure-

ment of the displacement of the dissipative elements. Calibration is accurate to 0.3 db and is not affected by humidity or temperature variation. The general attenuation range is 0.5 to 40 db with a calibration accuracy of 0.2 db. Maximum VSWR is 1.15. —Narda Corp., Mineola, New York.

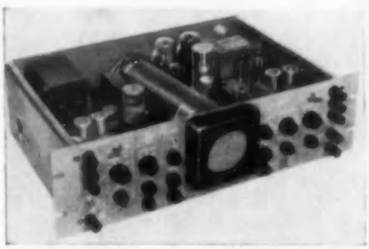
Circle No. 14 on reply card



PATTERN GENERATOR

Arbitrary pulse pattern of negative and positive pulses is the output of a pulse pattern generator offered for checking digital computer memory devices, shift registers, etc. It contains a master pulse burst generator delivering up to 64 bits spaced from 8 to 100,000 microsec, and two or more burst generators triggered by the master to deliver up to 16 pulses, positive or negative, spaced and lasting from 1 to 1,200 microsec.—Wang Laboratories, 37 Hurley St., Cambridge 41, Mass.

Circle No. 15 on reply card

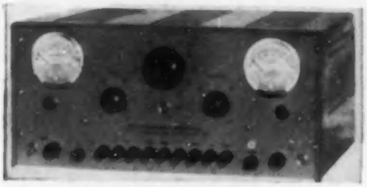


LOW FREQUENCY SCOPE

A compact low-frequency oscilloscope has been developed with a response up to 500 kilocycles. This response is flat to within 3 db from 0 to 300 kilocycles. Horizontal and vertical amplifiers are identical, assuring accurate phase-angle measurements, and the instrument is sensitive to both direct and alternating current voltages. The unit is packaged to fit in standard 19-in. relay racks or cabinets. —Hycon Mfg. Co., Pasadena, Calif.

Circle No. 16 on reply card


the F-104A
goes steady with Lear
The faster-than-thought speed of the Lockheed F-104A Starfighter has been made practicable by the automatic flight control system designed and produced by Lear in collaboration with Lockheed engineers. By damping out undesired oscillations in *all* axes more quickly than they can even register in a pilot's brain, Lear's 3-axis stability augmenter provides an ease of control comparable to a basic jet trainer.
Lear Inc.
Santa Monica, California



THERMOCOUPLE REFERENCE

Thermocouple reference junction provides 24 separate thermocouple units with a choice of iron-constantan, chromel-alumel, or chromel-constantan in each of 12 independent circuits. At a reference temperature of 150 deg F, for which thermocouple tables are available, the rated accuracy is ½ deg F under normal ambient conditions.—Pace Engineering Co., 6914 Beck Ave., North Hollywood, Calif.

Circle No. 17 on reply card

TRANSISTOR CHECKER

This junction transistor checker measures the significant characteristics of PNP or NPN transistors, namely collector leakage with base grounded, collector current at zero base current, and base-to-collector current gain at 4.5 volts on the collector. The unit has self-contained batteries and does not require any warm-up time. The meter reads gain directly, showing up defective units and indicating relative gain.—Alfred W. Barber Laboratories, 32-44 Francis Lewis Blvd., Flushing, New York.

Circle No. 18 on reply card

DELAY LINE

A pushbutton decade delay line is now available with a calibration accuracy evaluated at plus or minus 1 percent of the selected delay. Voltage rating for this new unit is 500 volts dc and delays are up to 2.1 microsec. Specifications for one model: impedance, 1,000 ohms; rise time, 2.0 microsec, and total attenuation, 50 percent at 50.1 microsec delay.—Esc Corp., 534 Bergen Blvd., Palisades Park, N. J.

Circle No. 19 on reply card

FREQUENCY METER

A new frequency meter permits direct digital frequency readings from one cps to 42 mc, and also functions as a frequency ratio meter, 0 to 1 megacycle period meter, 1 microsec to 10 million sec time interval meter, 0 to 2 megacycle event per unit time meter, and last but not least, a high-speed straightforward counter.—Beckman Instruments, Inc., 2200 Wright Ave., Richmond 3, Calif.

Circle No. 20 on reply card

DC VOLTMETER

Here is a self-calibrating dc voltmeter which provides accuracies of better than one-half of 1 percent over a wide range. It utilizes the potentiometer-null-balanced method of measurements. The balancing voltage is taken off a calibrated 10-turn potentiometer connected across an internal 1½-volt dry-cell. The full-scale ranges are 1, 2, 5, 10, 20, 50, 100, 200, 500, and

1,000 volts dc with an overall input resistance of 10,000 ohms per volt. Maximum current drain on a built-in voltage source is 1.0 ma.—Nucleonics Engineering Laboratories, Inc., 32 Manadnock Rd., Wellesley Hills 81, Mass.

Circle No. 21 on reply card

PRIMARY ELEMENTS

PYROMETER

Transmitting potentiometer pyrometer with automatic electric thermocouple cold-junction compensation is available to span from 200 to 3,000 deg F. The sensitivity of the instrument is 0.003 millivolts per 0.1 deg F, with an accuracy of plus or minus 1 percent. The line voltage error is plus or minus ¼ percent of the span, while the ambient temperature error is plus or minus 1 per cent of the span. The overall speed of response of the instrument is 0.2 sec.—Manning, Maxwell & Moore, Inc., Stratford, Conn.

Circle No. 22 on reply card

PRESSURE PICKUP

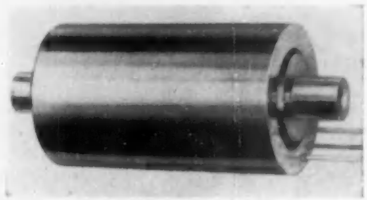
Thimble-sized pressure pickup is designed for high-vibration and temperature applications. Because it will withstand a continuous 600 deg F, the maker says it more than doubles the existing temperature range for this type of transducer. A diaphragm and strain gage do the job.—Consolidated Electrodynamics Corp., 300 N. Sierra Madre Villa, Pasadena, Calif.

Circle No. 23 on reply card

FORCE TRANSDUCER

Special force transducer has a load-cell of 20,000 lb-capacity with maximum deflection of only 0.0005 in. under full load. It has a natural mechanical frequency response of about 1,900 cps and will respond to full thrust capacity in 3 microsec.—Baldwin-Lima-Hamilton Corp., Philadelphia 42, Pa.

Circle No. 24 on reply card



TORQUE TRANSDUCER

Torque transducer has no mechanical or electrical contacts between rotating shaft and pickup housing. Reproducibility of 0.1 percent and resolution of 0.02 percent permit the use of one instrument in a wide range of torque measurements. Various models are available for ambient temperatures from minus 145 to plus 1,200 deg F while the linearity of all models is 2 percent.—Crescent Engineering and Research Co., 11632 McBean St., El Monte, Calif.

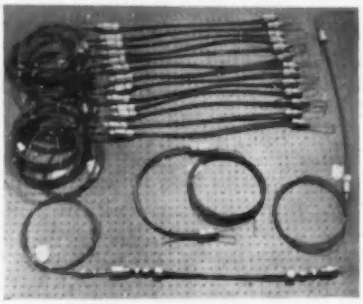
Circle No. 25 on reply card

SERVO TACHOMETER

A size-15 tachometer-servomotor combination, featuring an accurate and stable generator section, has been de-

veloped. The null-voltage of the drag-cup tachometer is said to be a maximum of 8 millivolts in-phase and approximately 10 millivolts quadrature. The output voltage of the generator is 3.2 volts per 1,000 rpm with an input of 115 volts, 400 cps on phase 1 and 115 or 230 volts on the control phase. The output torque of the motor is rated at 1.5 in.-oz at stall. The no-load speed is 4,500 rpm.—Basler Electronics, Inc., Highland, Ill.

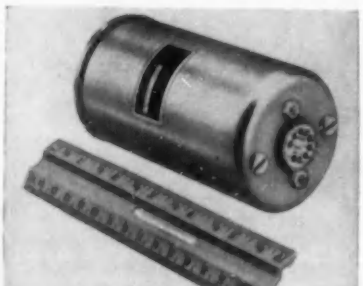
Circle No. 26 on reply card



THERMOCOUPLE GLANDS

Wire thermocouple glands provide easy entrance into pressure vessels of 1, 2, 4, 6, or 8 wires by an exclusive method of sealing bare wire at pressures from full vacuum to 20,000 psi. Glands may be operated from minus 300 to plus 1,850 deg F.—Conax Corp., 7811 Sheridan Dr., Buffalo, N. Y.

Circle No. 27 on reply card



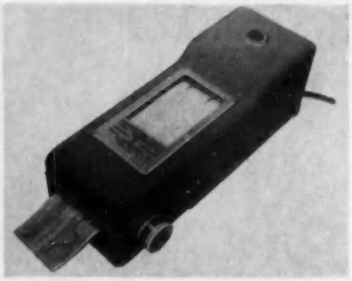
RATE GYRO

New rate gyro is powered by a dc motor and governor-controlled so that the outupt is independent of line voltage. The unit also incorporates a dashpot for damping, and the natural frequency of the gyro is in the range of 5 to 10 cps. The overall size is 2⅜ in. in diameter by 4$\frac{3}{16}$ in. long. The total

weight is 1.7 lb.—Globe Industries, Inc., 1785 Stanley Ave., Dayton 4, Ohio.

Circle No. 28 on reply card

CONTROLLERS, INDICATORS, & RECORDERS



OSCILLOGRAPH RECORDER

Electrodynamic oscillograph recorder incorporates critical acoustic damping and produces two rectilinear oscillograph tracings. This recorder has a frequency range from dc to 200 cps, and a sensitivity of 200 microamps rms for full-scale deflection. Variable speed ranges are from 0.01 sec per division to 1 sec per division. The overall time resolution is 1 millisec. The unit, a two-channel recorder, weighs 10 lb.—Massa Laboratory, Inc., Hingham, Mass.

Circle No. 29 on reply card

THERMOSTATS

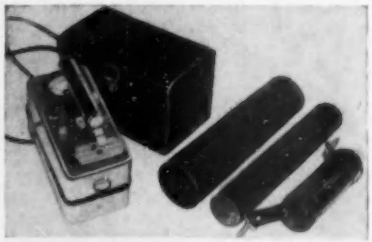
Sealed thermostats will withstand acceleration up to 50 g and are not damaged by vibration up to 0.031 in. amplitude at frequencies of 0 to 60 cps. Slow make and break operating principle eliminates mechanical snap action; under favorable conditions unit can operate on temperature differentials as low as 0.2 deg C.—Thomas A. Edison Inc., West Orange, N. J.

Circle No. 30 on reply card

PORTABLE CONTROLLER

Miniature portable controller consists primarily of an electronic switch which is capable of controlling 500 watts of power, either delivered at 115 vac, 60 cps, or switched by its internal contacts. Separate fusing of input and output circuits is provided.—Autron Engineering, Inc., 1254 W. 6th St., Los Angeles, Calif.

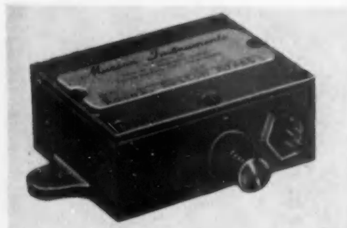
Circle No. 31 on reply card



GEIGER COUNTER

A geiger counter that provides from 10 to 50 times more actual gamma sensitivity than conventional geiger tubes is now on the market. The increase in sensitivity is obtained without sacrificing any desirable characteristics, such as temperature independence up to 200 deg F, reliability, ruggedness, and cost advantage. This novel unit is especially effective on low-level gamma rays, making the counts extremely sensitive to the weakened radiation at low level or deep sources.—Radiac Co., 489 Fifth Ave., New York City.

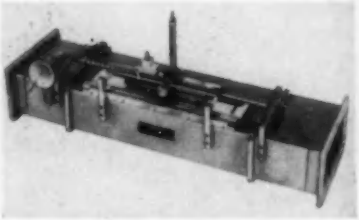
Circle No. 32 on reply card



ACCELERATION CUT-OFF

Acceleration-sensitive switches are designed for safety circuits and instrumentation setups and are set off at predetermined acceleration levels between 2.5 to 15 g. One model makes contact only during the established over-g condition, the other requires manual resetting.—Maxson Instruments, 47-37 Austell Pl., Long Island City 1, N. Y.

Circle No. 33 on reply card



VSWR INDICATOR

L-band slotted line measures magnitude and phase of voltage standing wave ratios in standard L-band waveguide at frequencies from 1,120 to 1,700 mc. This unit can be used with any standard probe and provides a residual VSWR of less than 1.05. The coupling between the wave-guide and the coaxial section is designed to provide a low VSWR (maximum 1.20) over the entire frequency range. —Vectron, Inc., 1613 Trapel Rd., Waltham 54, Mass.

Circle No. 34 on reply card

DIGITAL TIMER

Digital timer is a compact, four decade, electronic counting instrument designed for rack-mounting or portable use. It will respond to counting rates as high as 60,000 cps with an accuracy of 0.005 percent plus or minus one count. Time is indicated in units of 100 or 1,000 microsec. Time is registered by counting pulses generated by an internal 100-kc crystal-controlled oscillator for an interval determined by internally applied stop and start impulses. The start and stop impulses are adjustable from 6 to 100 volts positive or negative polarity. The counter itself responds to input signals which are 15 volts peak minimum input.—Hupp Instrumentation Co., Los Angeles, Calif.

Circle No. 35 on reply card

PRESSURE CONTROLLER

This simple open-loop control unit protects gas distribution systems. Designed for use in intermediate and high-pressure pilot-loaded distribution circuits, the new system enables an operator at a central control station to raise or lower the pressure settings on pressure regulators 10 to 15 miles away. The unit incorporates many safety features, among which is fast pressure change: 15 min for 250 psi, 2.7 min for 4.5 psi.—Rockwell Mfg. Co., 400 North Lexington Ave., Pittsburgh 8, Pa.

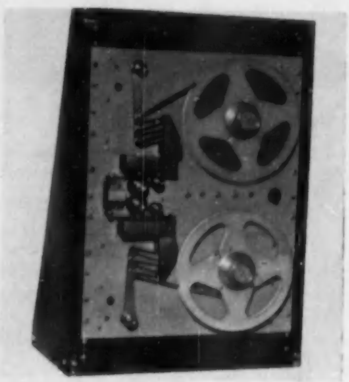
Circle No. 36 on reply card

NEW PRODUCTS

MAG AMP CONTROLLER

Magnetic amplifier motor speed control utilizes the amplifier to effectively measure the operating speed of the motor by sensing armature current and voltage drop and applying an instantaneous correction voltage whenever load conditions or other effects threaten a speed change. The unit provides a means for presetting speeds of small motors by means of a conventional 2-watt rheostat, remotely located if desired, which will maintain the motor speed regardless of changing load conditions. The unit can be attached to any universal series 115-volt motor from 1/50 to 1/15 hp.—CGS Laboratories, Inc., 391 Ludlow St., Stamford, Conn.

Circle No. 37 on reply card



TAPE HANDLER

Start and stop time of this new digital magnetic tape handler is less than 5 millisec; complete remote control of start, stop, reverse, and change of speed function are provided. Standard models have either 6 or 8 tracks and dual-tape speeds of 60/15 or 30/15 in. per sec.—Key Electric Corp., 287 Post Ave., Westbury, L. I.

Circle No. 38 on reply card

DIGITAL PRINTOUT

Numerical voltmeter has been converted for use with digital printout equipment such as card and tape punches. The voltmeter circuits are accurate to within 2 percent for ac, and within 0.1 percent for dc. Resistance ranges up to 10 megohms are also accommodated.—Hycon Electronics, Inc., 321 S. Arroyo Pkwy., Pasadena, Calif.

Circle No. 39 on reply card

FOR AIRBORNE TESTS

This new amplifier with an isolated input circuit is particularly suited for airborne thermocouple or strain gage measurements. The unit has a rise time of less than 5 millisec and a flat response from dc to 400 cps. The output ranges from 0 to 5 volts dc. Over the range of frequencies the response is down by a factor of 3 db at 400 cps and the zero drift resulting from environmental extremes is less than 200 microvolts total spread. The amplifier is constructed and packaged to withstand all extremes of temperature and shock usually experienced in airborne operation.—Doelcam Div. of Minneapolis-Honeywell Regulator Co., 1400 Soldiers Field Rd., Boston, Mass.

Circle No. 40 on reply card

TIMING MOTOR

Hysteresis timing motor develops as much as 10 oz-in. of synchronous torque at 1 rpm. The motors operate from 115 or 230 volts, 60 cps. One or two-way frictions are available and an especially heavy-duty gear-train permits continuous transmission of the full output torque of the motor.—Haydon Mfg. Co., Torrington, Conn.

Circle No. 41 on reply card

POWER SOURCES

TRANSISTOR POWER SUPPLY

A small size switching transistor power supply, available with dc outputs of 100, 250, 300, 400, and 600 volts, delivers power up to 60 watts maximum. The switching transistor cir-

cuit is designed in such a way that no derating from minus 55 to plus 80 C is required.—Arnold Magnetics Co., 5962 Smiley Dr., Culver City, Calif.

Circle No. 42 on reply card

DC POWER SUPPLY

A dual, magnetically regulated dc power supply, offering an output range of 3 to 36 volts at 15 amp, gives static regulation of plus or minus 0.25 percent, less than 50 millivolts ripple for the entire voltage range, and dynamic regulation of less than 1 percent for a 10 percent line transient or below 1.5 volts for a 10 percent load transient. Response time is less than 25 millisec for line transients and 150 millisec maximum for load transients. The input requirements are 80 to 150 volts at 57 to 63 cps.—Magnetic Research Corp., El Segundo, Calif.

Circle No. 43 on reply card

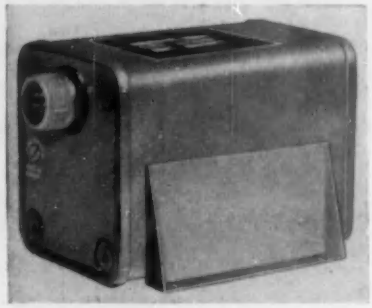
POWER SUPPLY

16-kv power supply fits in your hand. It's a compact transistorized dc power supply that produces 16,000 volts

NEW PRODUCTS

with as little as 3 volts input. The unit weight is 1½ lb and is only 1½ in. by 3 in. by 6 in. Special models will operate over the temperature range of minus 65 to plus 100 deg C. The operating efficiency is approximately 85 percent.—Universal Atomic Corp., 19 E. 48th St., New York 17, N. Y.

Circle No. 44 on reply card



TUBELESS POWER SUPPLY

A new 5-volt dc tubeless power source will provide efficient performance at altitudes up to 60,000 ft. Magnetic flux oscillator circuitry effectively isolates line voltage transients from the output and regulates dc to 0.1 percent accuracy. The output capacity of the unit is 1 amp and provisions for output adjustment are provided. The dynamic regulation is 1 percent for line voltage transients of 10 volts. The unit operates on 115 volt, 400 cycle aircraft supplies.—Magnetic Research Corp., El Segundo Calif.

Circle No. 45 on reply card

PROGRAMMABLE SUPPLY

Programmable power supply can be operated from remote locations or programmed in accordance with commands from a control system. It will supply an output of 0 to 300 volts with a regulation of 0.1 volt and a ripple of 1 millivolt. Current outputs for the various units range from 0 to 100 milliamp to the largest unit which will produce 0 to 300 milliamp.—Electronic Measurements Co., Inc., Lewis St., Eatontown, N. J.

Circle No. 46 on reply card

KILOWATT SUPPLY

Regulated 80-kilowatt power supply provides up to 20 kilovolts dc output at 4 amp, with less than 1 percent

ripple. It will operate from a 208-volt, three-phase, 60-cps input source and provide a continuously variable output, from 0 to full-rated load, with a regulation to within 15 percent.—Mason Laboratories, 207 Greenwich Ave., Stamford, Conn.

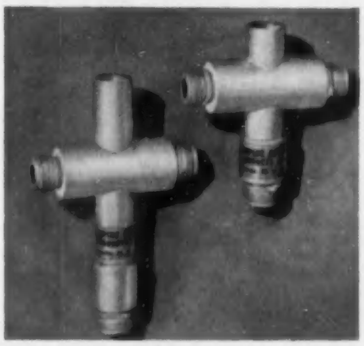
Circle No. 47 on reply card

COMPONENT PARTS

TANTALUM CAPACITOR

This series of solid tantalum capacitors range from 1 mfd at 35 working volts dc to 350 mfd at 2 volts. They are potted and hermetically sealed in metal cases, assuring maximum resistance to thermal and mechanical shock, with no altitude or humidity problems.—Fansteel Metallurgical Corp., North Chicago, Ill.

Circle No. 48 on reply card



POWER DIVIDER

Power divider splits microwave power without losses. Because of matched transformers rather than dissipative networks, the division of power is accomplished with zero insertion loss. The power at each output is exactly half of that at the input with a balance between outputs of 40 db or better. The five models cover the frequency range from 800 to 10,000 mc.—Empire Devices Products Corp., 58-15 Bell Blvd., Bayside, N. Y.

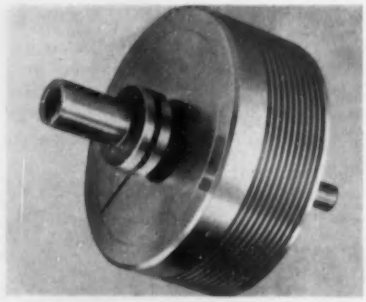
Circle No. 49 on reply card

NEW PRODUCTS

MAG AMP

This magnetic amplifier, although small and compact, has a full linear output of 7.5 volts for a 300-microamp input. The dc to dc unit is powered directly on 115 volts, 400 cps. The bandwidth is at least 8 cps for each 1,000 ohms in the control loop. Access to two independent control windings enable the amplifier to be used in summing or multiplying circuits.—Airpax Products Co., Middle River, Baltimore 20, Md.

Circle No. 50 on reply card



HYSTERESIS CLUTCH

High torques from low control currents is a major sales claim for a new hysteresis clutch. Offered for proportional torque control applications, it will deliver up to 140 oz-in. for an input of only 65 ma. at 78 vdc. The coil resistance is 1200 deg. It's 4½ in. long and 3¾ in. in diam.—American Electric Motors, Miniature Components Div. of American Electronics, Inc., 655 W. Washington Blvd., Los Angeles 15, Calif.

Circle No. 51 on reply card

DELAY LINE

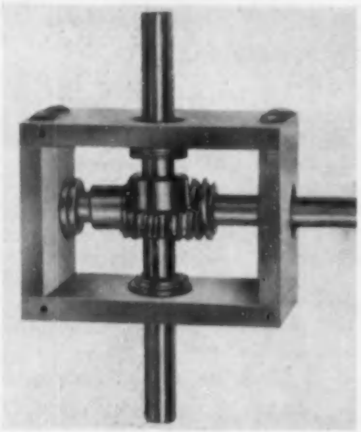
20.3 microsec delay line has taps every 1.45 microsec with a tap accuracy of plus or minus 0.1 microsec. Rise time is better than 0.7 microsec with a total attenuation of less than 4 db. Excellent phase linearity also claimed.—Epsco Corp., 588 Commonwealth Ave., Boston, Mass.

Circle No. 52 on reply card

PULSE TRANSFORMERS

Sub-miniature pulse transformers that offer very fast rise time and exceptionally high duty cycles are now available. These units weigh approximately 1/10 oz. and have maximum voltage ratings of 1,000 volts dc. They are capable of repetition rates of 5 to 6 mc. and provide up to 40 percent duty cycles without backswing.—Allen B. DuMont Laboratories, Inc., 760 Bloomfield Ave., Clifton, N. J.

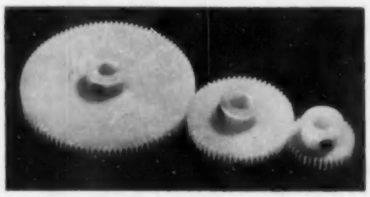
Circle No. 53 on reply card



GEAR REDUCER

Right angle gear reducer is available with bevel or worm gear drive in ratios of 1:1, 2:1, 3:1, 5:1, 10:1, and 20:1. Assemblies are housed in anodized aluminum dustproof housings measuring 1 in. by 1½ in. by 1½ in. with gears permanently pinned to stainless steel shafts mounted in bronze bearings with constant pressure thrust washers.—Jan Hardware Mfg. Co., 75 North St., Brooklyn, N. Y.

Circle No. 54 on reply card

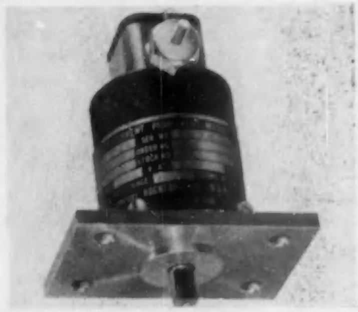


SPUR GEAR

New nonmetallic spur-gears are immediately available in both nylon and linen phenolic materials. The gears come in pitch sizes of 48, 64, 72, and 96 pitch, and have bores of 1/8, 3/16 and 1/4 in. All gears are cut to AGMA precision 1 tolerances.—Pic Design Corp., 160 Atlantic Ave., Lynbrook, New York.

Circle No. 55 on reply card

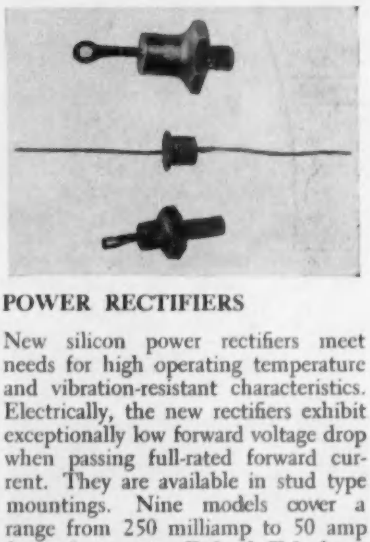
NEW PRODUCTS



TACH GENERATOR

Permanent magnet tachometer generators are available in three frame sizes with maximum rated outputs of 7,000 rpm or 100 volts, whichever occurs first. They are capable of supplying output voltages of up to 40 volts per 1,000 rpm within plus or minus 0.5 percent linearity over the operating range, with very low slot and commutator ripple.—Aircraft Controls Div. of Barber-Colman Co., 1400 Rock St., Rockford, Ill.

Circle No. 56 on reply card



POWER RECTIFIERS

New silicon power rectifiers meet needs for high operating temperature and vibration-resistant characteristics. Electrically, the new rectifiers exhibit exceptionally low forward voltage drop when passing full-rated forward current. They are available in stud type mountings. Nine models cover a range from 250 milliamp to 50 amp forward current.—Federal Telephone & Radio Co., 100 Kingsland Rd., Clifton, N. J.

Circle No. 57 on reply card

SHUT-OFF VALVE

A toggle-operated shut-off valve has been designed to handle liquids or gases for any pressure up to 3,000 psi. This new valve will provide leak-proof shut-off for hydraulic or pneumatic service and operates smoothly and easily up to their full rated capacity—James Pond-Clark, Pasadena, Calif.

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(100) SUBMINIATURE SWITCHES. Micro Switch Div. of Minneapolis-Honeywell Regulator Co. Catalog 75a, 16 pp. Describes and pictures basic assemblies, environment-free subminiature switches and actuators, illuminated and light force switches, and a new series of sealed, multi-circuit toggle switch assemblies.

(101) MICROWAVE COMPONENTS. J-V-M Engineering Co. Catalog, 22 pp. Features standard and custom-engineered microwave components and mechanical assemblies. Microwave components range from dc to 40,000 mc; include cavities, adapters, bends, attenuators, loads, tees, twists, directional couplers, accessories.

(102 VARIABLE FREQUENCY OSCILLATOR. Technical Material Corp. Bulletin 193, 4 pp. Presents data on TMC Model PMO-3, which may be used as a variable frequency oscillator, exciter, and heterodyne frequency meter. Gives direct reading over basic range of 2000-4000 kc.

(103) MICROWAVE PACKAGES. Philco Corp. Booklet, 16 pp. Describes typical expandable microwave systems for 90, 120, 500 miles, including photos and diagrams of actual Philco industrial installations. Includes specifications for new CLR-7 microwave equipment. Systems may be used for voice, facsimile, program, and high-speed data transmission.

(104) SERVOMOTORS. John Oster Mfg. Co. 4 catalog sheets. Each sheet includes two graphs, dimensional drawings, average characteristics, and electrical data for a low-inertia servomotor.

(105) AERODYNAMIC TESTING. Hagan Corp. Booklet MSP-133, 20 pp. Describes "PowrAmp" series of components, a high-speed, high-powered line of precision electrical and electronic control equipment. This series is designed for aeronautical testing and other jobs requiring exact performance.

(106) PLUG-IN UNITS. Goodyear Aircraft Corp. Bulletin, 6 pp. Gives details of servo plug-in units which increase the scope and versatility of the Geda L3 linear and N3 nonlinear analog computers. These multipliers, function generators, and resolvers generate products of variables and arbitrary functions of variables and feature excellent low-frequency response.

(107) SIMULATION. Berkeley Div. of Beckman Instruments, Inc. Booklet, 4 pp. This is the paper Hugo Martinez, Berkeley consultant, gave at the National Conference on Industrial Hydraulics last fall. It gives a "short course" in mathematical simulation—analog computing.

(108) PRECISION OSCILLOGRAPHS. Midwestern Instruments. Two booklets, each 8 pp. One of these booklets describes several series of precision oscillographs, their galvanometers, and associated instruments. The other fully portrays the 590 and 591 recording oscillographs, which are designed to maximize versatility, accuracy, and ruggedness.

(109) RECEIVING TUBES. General Electric. Booklet ETD-1212-A, 20 pp. Contains description, characteristics, construction features, and application data for the G-E micro-miniature metal-ceramic receiving tube 6BY4. This tuner triode is the first of a line of similar tubes, ranging from diodes to high-power triodes.

(110) DIFFERENTIAL REFRACTOMETER. Barnes Engineering Co. Booklet, 8 pp. This brochure explains the theory and principles of refractometry—particularly continuous measurement of the refractive index—as applied to the process industries. It also gives complete specifications of the company's three available differential refractometers.

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(111) MAGNETIC TAPE. Minnesota Mining & Mfg. Co. Booklet, 12 pp. Lists physical and magnetic properties of 12 "Scotch" brand magnetic tapes and films.
(112) pH AND CONDUCTIVITY. Industrial Div. of Minneapolis-Honeywell Regulator Co. Catalog 1551, 20 pp. Includes information about the company's latest equipment for measuring, recording, and controlling the electro-chemical variables, pH, Redox, and conductivity. Also reviews the fundamentals of electrochemical instrumentation.
(113) CONAX CATALOG. Conax Corp. Catalog 1556, 28 pp. Gives specifications, and prices for the firm's thermocouple assemblies and pressure sealing glands. Introduces "Speedwell" protection tubes, multiple wire thermocouple glands, pressure-sealing spring-loaded thermocouples, and "Flex-tube" assemblies.
(114) SUB-MINIATURE CONNECTORS. Cannon Electric Co., Bulletin D-6, 8 pp. Contains specifications, applications, photographs of type "D" connectors, designed for miniature equipment requiring rack and panel chassis construction.
(115) MAGNETOSTRICTION. International Nickel Co. Booklet, 24 pp. This treatise explains the principle of magnetostriction—the tendency for a ferromagnetic material to expand its dimensions parallel to a magnetic field and contract the others—and some of its uses (e.g. sonar). Extensive use of graphs.
(116) TRACING ATTACHMENT. Pratt & Whitney Co. Bulletin, 4 pp. This Kellering attachment follows any three-dimensional model accurately without touching it by means of a high tension spark gap between the attachment and the model. It can't damage the softest or most fragile model. It has a range of spindle speeds from 300 to 10,500 rpm and can be adapted to most milling machines.
(117) THERMOCOUPLE DATA. Wheelco Instruments Div. of Barber-Colman Co. Booklet F-5228-3, 40 pp. Discusses construction and industrial control applications of thermocouples and radiation detectors. Included are standard temperature-millivolt equivalents, using 1948 International Temperature Scale.
(118) DATA TRANSMISSION. Simplex Valve & Meter Co. Bulletin 700, 16 pp. Describes the "Orthoflow" system for electrical transmission of metering data, which is particularly applicable in water and sewage waste jobs. It can transmit over private wires or leased telephone lines.
(119) PERIODICAL. "The Right Angle", published periodically by Sanborn Co., 8 pp. Contains technical information for users and potential users of oscillographic recording equipment. Two recent features: "Zero Suppression Circuits", "Frequency Deviation Preamplifier".
(120) TRIAD CATALOG. Triad Transformer Corp. Catalog TR-56, 32 pp. The company's new general catalog describes and illustrates nearly 700 items, 76 of which are new to the line.
(121) MAGNETIC STARTER. Cutler-Hammer, Inc. Bulletin EE-191. New features in an ac magnetic motor starter include snap-on contact block cover, visual or audible alarm circuit, and plastic-covered coil insulation.
(122) PRECISION RESISTORS. International Resistance Co. Bulletin D-1a, 4 pp. Gives comprehensive data on winding technique, testing, tolerance, inductance, insulation, terminals, temperature coefficient, etc. of IRC Mil Type precision wire wound resistors.
(123) CAPTURED TRANSIENTS. Hughes Products Div. of Hughes Aircraft Co. Bulletin, 4 pp. The "Memotron" direct display storage tube retains transients and other nonrecurring phenomena visually as long as desired, permitting examination at leisure without photography. Uses range from electrocardiography to analog computer readout.
(124) MICRO TIPS DIGEST. Micro Switch Div. of Minneapolis-Honeywell Regulator Co. Booklet, 16 pp. Compiles best ideas for use of snap-action switches, as published in "Micro Tips". Applications will improve safety, lower costs, increase production, and help automate.
(125) PRECISION RELAYS. Manning, Maxwell & Moore, Inc. Bulletin MRM-340, 4 pp. Describes two precision relay series, one for high action limit, and one for low action limit. Both series feature positive switching action within 0.5 percent repeatability, contact ratings up to 10 amp at 115 vac, and plug-in chassis.
(126) POWER TRANSMISSION. Lovejoy Flexible Coupling Co. Booklet, 12 pp. Covers the firm's line of power transmission equipment, including flexible couplings, variable speed pulleys and transmissions, universal joints, and motor bases. Information includes operating data, hp ratings, sizes, and types for various applications and working conditions.
(127) METER THAT PUMPS. Hills-McCanna Co. Booklet, 8 pp. Models of this precision small flow metering and proportioning pump will handle maximum flows from 11 cc/min to 6 gal/hr (379 cc/min). Highlights of the new models are maintenance ease and improved accuracy at small flow rates. Schematic is included.
(128) RADIO INTERFERENCE. Stoddart Aircraft Radio Co. Booklet, 4 pp. Presents facts about Stoddart's radio interference and field intensity measuring equipment. According to the maker, the apparatus performs important functions heretofore beyond the scope of tunable 30-15,000 cps equipment.
(129) INFRARED SPECTROPHOTOMETER. Beckman Instruments, Inc. Bulletin 472-A, 4 pp. Pushbutton opera-

tion enables any technician to perform analyses with this device after it is set up by a qualified operator. Chart paper automatically aligned for successive runs.

(130) METER-TRANSMITTER. Askania Regulator Co. Booklet, 8 pp. Introduces "Transometer", a positive displacement flow meter and pneumatic signal transmitter. Device applicable for flow, ratio, fuel, and combustion control.

(131) "TECHNIQUES". Barnes Engineering Co. Magazine, 16 pp. "Infrared Radiometry" is the subject of the principal article in the Spring 1956 issue of this publication. The issue is primarily concerned with its application to remote temperature measurement.

(132) SERVOMECHANISMS. Pegasus Laboratories, Inc. Bulletin, 4 pp. Lists products and prices of the company's electrohydraulic servo equipment—electro-mechanical and instrumented hydraulic actuators and electronic equipment.

(133) THERMISTORS AND VARISTORS. Victory Engineering Corp. Catalog, 20 pp. Contains info on "Veco" thermistors, varistors, and assembles, including complete electrical and physical characteristics of bead, disc, rod, and washer type themistors and other products. Describes such special products as thermistor hypodermic needles combustion analyzers, gas analysis cells.

(134) DC MOTORS. Aircraft Controls Div. of Barber-Colman Co. Bulletin F-4344-3, 4 pp. Condensed catalog sets forth line of fractional hp dc permanent magnet motors, gearheads, centrifugal blowers, and tach generators. Motors have voltages of 6-115 vdc, speeds of 5,000-20,000 rpm, outputs to 1/10 hp.

(135) MALFUNCTION DETECTOR. Beta Corp. Bulletin 500-1A, 4 pp. Includes specs, photos, and drawings of vibration monitors and malfunction detectors. Also tells about devices' operation. 3 models: standard, oil-tight, explosion-proof.

(136) SPEED REDUCERS. Cone-Drive Gears Div. of Michigan Tool Co. Bulletin 600-C, 8 pp. Standard double-enveloping worm gear speed reducers are given greater overhung load capacity and longer life by employment of Timken tapered roller bearings on both worm and gear shafts.

(137) TAPE HANDLER. Key Electric Corp. Catalog sheet. Describes model 101 digital magnetic-tape handler, giving complete specs and description. Starts and stops on two capstans in 5 millisec.

(138) SENSING DEVICES. Richardson Scale Co. Technical Reference 55D, one sheet. Flow and level sensing devices give automatic safeguard against interruption or system failure by warning when lack of material supply or flow is detected in chutes, conveyors, hoppers, silos, etc.

(139) ENGLISH CONTROLS. Servomex Controls, Ltd. Bulletin, 6 pp. Gives essential features of ac voltage stabilizers, dc power supplies, variable speed drives, wave form generator, decade capacitor, and meter tester. Details given on request.

(140) CYLINDER MOUNTINGS. Hanna Engineering Works. Bulletin 76, 4 pp. To compensate for misalignment between air and hydraulic cylinders and their work loads, Hanna has developed universal cylinder mountings, which are similar to universal joints.

THE SHORTAGE OF SCIENTISTS AND ENGINEERS:

A Threat to Economic Progress

THERE are two paramount reasons for concern over the serious shortage of scientists and engineers that now confronts the United States:

- The first reason, with which this editorial deals, is that continued expansion of our economy and further increases in our living standards are threatened unless we train more scientists and engineers and use them more effectively.
- The second reason for concern is that we run the risk of falling behind the Soviet Union in the technology so essential to national security. The consequences of losing this race to the Russians are not comforting. (The possibility that this might happen over the next few years was discussed in an earlier editorial in this series.)

The crucial contribution of scientists and engineers to the well-being of the American people has been to find ways of making better use of limited resources, to make equipment more productive, to develop new and better products that enrich our lives, to enable us to live longer and be healthier. They have made this contribution with greater success in the last 15 years than ever before, but it has required progressively more resources and more trained people.

During this 15-year period our annual production of goods and services, in dollars of constant purchasing power, has almost doubled. Since our total population has increased only 25 percent, this has meant a tremendous rise in the economic well-being of the American people as a whole. But in accomplishing this, the number of scientists and engineers has been more than doubled.

Tasks for Research

If the American economy is to continue to grow and if our living standards are to show further improvement, the work of scientists and engineers must be stepped up even more in the years ahead. Unless answers to several pressing problems are found through intensified research efforts, economic progress will become increasingly more difficult.

Productivity per hour of labor must be increased at a faster rate. Improved medical care has greatly increased the number of people who attain retirement age, and sharply higher birth rates since the war will mean larger numbers of children in school and college. Meantime, because of low birth rates during the depression, the number of people reaching working age is not rising nearly so fast. The result is that over the next 20 years our population will increase by about one-third, while the total manhours worked are not expected to increase more than 15 percent. So, simply to maintain the same living standards for a rising population — with no provision for additional improvements — ways must be found to enable each worker to produce for more dependents.

It is primarily to the scientists and engineers that we must look for help in making human labor more productive. This will require enormous increases in our power

resources. We will need to make more effective use of our existing fuel supplies — coal, oil and natural gas. And we will have to devise economically practical means of tapping other energy sources, particularly nuclear power and new rocket fuels.

Also, better ways must be found to use scarce and low-grade raw materials. Thanks to great strides in metallurgy and mining techniques, we are now utilizing sources of copper and iron ore that, for all practical purposes, were not available to us only ten years ago. Similar strides are needed in the mining and processing of bauxite if low-grade domestic ores are to help satisfy a fast-growing market for aluminum. And stubborn technical obstacles in the area of "high temperature" metals—such as nickel, cobalt, columbium, tantalum and titanium — are impeding progress in jet and turbine engines.

These are only a few of the challenging tasks that demand intensified research and engineering activity in the years immediately ahead if the United States is to continue to raise living standards. We need more houses, schools and highways for a rising population, more medical research to reduce further the ravages of illness, more research in chemistry and other sciences to sustain the flow of new and improved products that are so essential an ingredient of our economic progress.

Ceiling on Growth

American industry has indicated that it is ready to meet the challenge and undertake vastly expanded research programs. A recent survey conducted by the McGraw-Hill Department of Economics revealed that total research and development expenditures of American industry were almost $5 billion last year, 29% higher than in 1953. By 1959 business plans to be spending well over $6 billion on research and development. And the total could well prove to be much higher, based on the trend of recent years.

But industry's programs for research and development cannot be carried out unless enough qualified research workers and engineers are available. Ernest R. Breech, chairman of the Ford Motor Company, recently described the supply of engineers as the "ceiling on our future growth." He gave force to his point by announcing: "If 900 qualified engineers were to approach us next week looking for jobs, we would hire every one." The U. S. Bureau of Labor Statistics found in interviews with some 200 large companies at the end of 1954 — a recession year — that at least half were unable to hire enough research scientists and engineers to meet their needs. A third of the companies reported substantial shortages of technical personnel.

The shortage of technically trained people, furthermore, is becoming more acute. The number of engineers and scientists now being graduated is only about enough to cover replacement requirements, while the needs of industry, government and education are mounting every year. According to the best information available — as indicated in the first editorial in this series — these needs are now about twice as great as our current engineering graduating classes and annual production of scientists with Ph. D. degrees.

To perform the research needed to remove roadblocks to our economic progress — and at the same time hold our own in the technology essential to our security as a free nation — we must have an adequate supply of men and women with engineering and scientific training. Instead, we are faced with an acute shortage, now and for several years to come. Reasons for the shortage and proposals for working our way out of the shortage will be discussed in the remaining two editorials in this series.

This is one of a series of editorials prepared by the McGraw-Hill Department of Economics to help increase public knowledge and understanding of important nationwide developments of particular concern to the business and professional community served by our industrial and technical publications.

Permission is freely extended to newspapers, groups or individuals to quote or reprint all or parts of the text.

Donald C McGraw

PRESIDENT

McGRAW-HILL PUBLISHING COMPANY, INC.

(Continued from page 32)

specialists became convinced of the possibilities for machine translation, the necessary components were nursed toward perfection. In 1955 Locke, Booth, and a few others presented their ideas in a book titled *Machine Translation of Languages*, published by MIT and John Wiley & Sons, Inc. (CtE, August '55, p. 113). Even then, however, no real instrumentation had been designed.

Now **International Telemeter Corp.** has signed a contract with the Air Force for development of a new type of information storage unit, a component specifically designed for automatic translation of Russian into English.. Work on the photoscopic device, which converts coded information on a transparent disc to electrical signals, is under the supervision of Dr. Gilbert W. King, author of "A New Approach to Information Storage" (CtE, August '55, p. 48).

The disc consists of 0.0003-in. squares, 6 million to the square inch, located on 600 tracks. As the disc spins at 1,200 rpm, the information in the tracks is read at a rate of 1 million bits per second by a light spot directed by an electron beam in a cathode-ray tube. Access time to any one of the 30 million bits stored on the disc (equivalent to 5 million characters, or several books), is the time of one revolution, or 50 millisec. This can be reduced by additional reading heads.

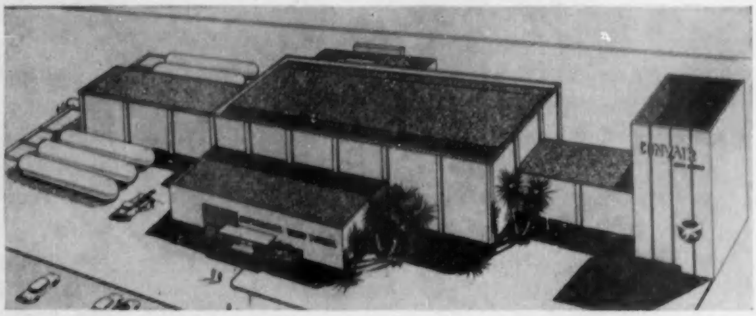
Although the unit has been designed for a definite purpose, there is no reason why it cannot service other areas, too. Among those listed by King: mail-order houses, telephone-directory publishers.

Approximately one month after International Telemeter signed the contract, R. E. Wall, Jr., of the University of Seattle, addressing a computer symposium of the AIEE in San Francisco, said, "There appear to be no insurmountable engineering problems in the realization of a mechanical translating machine . . . Research has progressed sufficiently to allow the formulation of a detailed program which should result in a commercially practical machine in a reasonable time. Much work remains to be done, most of which is linguistic in nature, but a substantial number of good engineering problems remain to be solved."

But to compete with human translators, Wall said, a mechanical translator must turn out 25,000 words per hour. This estimate is based on a per-hour cost of machine time of $250, which is as much as a modern large-size digital computer costs per hour. "This figure," he added, "is somewhat arbitrary, but it is certain that one word per second is too slow, and 100 words per second is probably faster than necessary." An abstract of Wall's talk is in this issue, page 142.

Miniature Precision Bearings unveils Keene, N. H., home: no cold germs, viruses.

National Cash Register builds in Hawthorne, Calif: big prospects for computers.



A wind-tunnel for Convair: supersonic range exceeds anything in private industry.

▶ **Beckman Instruments, Inc.**, has established a **Data & Control Systems Dept.** for the development and production of high-speed electronic systems. At the same time, its **Berkeley Div.** has set up an **Analog Computer Dept.** and has announced that it has built the biggest analog computer ever assembled west of the Mississippi. Heading the new department at Fullerton, the home of the Corporation, is Taylor G. Fletcher. Two of the advanced engineering, testing and industrial systems to be created under his supervision are already in the works: one will be used with electronic computers in industrial process control, and the other to design and test aircraft, jet engines, and rockets.

With Joseph L. Hussey, formerly assistant chief engineer for computers, at its helm, Berkeley's new department will be responsible for sales, installation, field engineering, and design and development of special computer equipment. Hussey worked on Berkeley's original EASE analog computer. His former research and development duties will be taken over by Alan MacLane. The division's giant computer, 6 ft high and 60 ft wide, is being used by **General Motors' Allison Div.** in Indianapolis for simulating jet engines. An outstanding feature is its 12 automatically set "map readers", which use 80 function generators—five times the number used in previous analog computers—to investigate function contours made up of two independent variables.

▶ "White Alice", the Alaskan Integrated Communication Exchange network with which the Air Force intends to connect isolated cities and

defense installation in Alaska to established networks, will be operated and maintained by **Federal Electric Corp.**, a subsidiary of **International Telephone & Telegraph Corp.** The system, still a-building, will be completed by 1958.

▶ **Fischer & Porter Co.** will build an automatic data logger to be used by the Coast & Geodetic Survey of the U. S. Dept. of Commerce for recording tide table predictions. Up to now, the predictions, made by the tide-predicting machine located in the department's building in Washington, D. C., had to be read from dials and then manually logged on the tables. The F&P logger will change all this: the output shafts of the predictor will furnish information on maximum and minimum water heights, on the time at which they occur, on slack water time, and on the maximum velocity of the ebb and flood current. All this, accurate to 0.25 percent, will be automatically typed out.

▶ Between 100 and 200 specially trained employees moved last month into a $500,000 production laboratory in South Norwalk, Conn., to begin work on improved transistors to meet severest requirements. The laboratory is the home of **Sperry Rand Corp.**'s new **Semiconductor Div.**, whose technical staff has as its nucleus a group of semiconductor scientists who carried

B. J. Rothlein

S. M. Grafton

on preliminary investigations in transistors and diodes at Sperry's Lake Success, N. Y., headquarters. Dr. Bernard J. Rothlein, who conducted basic studies of semiconductor applications at Lake Success, is the new division's technical director, and Samuel M. Grafton, former administrative head for armament radar at Sperry, is its manager. The initial batch of semiconductors to come from tested prototypes will be used by other Sperry divisions in critical control applications.

At Salt Lake City, Sperry has made plans for a $1¼ million research and development facility to be known as the **Sperry Utah Engineering Laboratory.** Resident manager of the laboratory, whose projects are still under wraps, is Paul W. Vestige, former ground armament engineering head at

WHAT'S NEW

Sperry Gyroscope Co. He was responsible for the first designs of the Army's "Skysweeper" automatic aircraft weapon. The initial 50,000 sq ft of his Utah laboratory will open before the end of the year.

▶ **Hycon Mfg. Co.,** has moved its **Photographic Products & Special Products Div.** into a new **Camera & Instrument Div.,** which will specialize in development of systems and products for aerial reconnaissance and for instrumentation in the physical sciences. General manager is William C. McFadden, a vice-president. Other officers: Richard H. Perley, assistant general manager; W. Q. Nicholson, director of engineering; and Leroy A. Loftus and Paul W. Shadle, assistant chief engineers.

▶ **Sylvania Electric Products, Inc.,** is operating its new private communications network and data processing system at Camillus, N. Y. The combination of an 18,000-mile private communication network, custom-built by Western Union, and a complete Remington Rand Univac System appears to be the first of its kind in existence. It represents a milestone in what Don Mitchell, Sylvania president, and Marcel Rand, Remington Rand executive vice-president both termed the "administrative revolution": a further step in office-automation's effort to keep pace with factory-automation.

▶ **Tyron, Inc.,** has been organized at Cambridge, Mass., to carry out research, development, and manufacture on its own account or on a contract basis in the fields of mechanical and chemical processes, including heat transfer, combustion, fluid mechanics, corrosion, and materials of construction. President is Dr. Harold S. Mickley, who has been an associate professor of chemical engineering at **MIT** since 1948, and executive vice-president is Ernest P. Neumann, a former associate director of MIT's **Gas Turbine Laboratory.**

▶ **Hughes Aircraft Co.** has been awarded $39,405,851 worth of Air Force contracts for production and maintenance of armament control systems for interceptor planes. Broken down, the four contracts specify $38,060,299 for production of the systems, and $1,345,552 for maintenance.

▶ A new division has been organized by **Washington Machine & Tool Works, Inc.,** under two former **Minneapolis-Honeywell** men. The division, **General Components Co.,** will

engineer and manufacture electronic and electromechanical devices and systems. Its directors are Ivan C. Pedersen and Karl Schurr, most recently in aeronautic work at M-H.

Companies A-Building

▶ A home (52,000 sq ft) for the **Electronic Div.** of **The National Cash Register Co.** in Hawthorne, Calif. Here, by means of research and development in electronic computers and auxiliary equipment, NCR hopes to accomplish a three-fold objective: the adaptation of conventional cash register, and business machines to computer input devices; a complete computing system, consisting of computer and all periphery units; and a practical application of electronics to accounting problems, as indicated by a survey of system needs.

▶ A $3.5-million supersonic wind tunnel at San Diego for **Convair.** This "blow-down" model, boasting a supersonic range of Mach 5, greater than any privately owned tunnel in the industry, will have double walls of 8-in.-thick reinforced concrete and an exhausting chamber to reduce the sound of the released air. One of the companies sharing the Convair contract is **Consolidated Electrodynamics Corp.**, awarded $200,000 for design, construction, and installation of the high-speed data system. The facility will be in operation for calibration within the year, and for testing by the following August.

▶ A 50,000-sq-ft home for **Miniature Precision Bearings, Inc.**, in Keene, N. H. MPB's bearings, which have ID's as small as 1/40 in., are assembled in a room boasting the first commercial application of the filters of the type used in Oak Ridge's gaseous diffusion process. The filters screen out particles as tiny as one microinch in diam. including many cold germs and some viruses.

▶ An engineering laboratory (35,000 sq ft) in Goleta, Calif., for **Raytheon Mfg. Co.** When this facility is completed, in the spring of 1957, Raytheon will discontinue its Chicago equipment laboratory, whose personnel will make up more than a third of the 125 employes expected to work in Goleta. At the same time, Raytheon has leased a 1-million-sq-ft manufacturing, warehouse, and office facility in Andover, Mass., from **Textron, Inc.** An initial contingent of 1,000 employes is contemplated for the property, known as the Shawsheen Mill, one of New England's most modern textile plants.

▶ An addition (cost: $1,164,000 to **American Bosch Arma Corp.**'s subsidiary, **American Bosch Arma Missis-**

sippi Corp., in Columbus, Miss. This will more than double the size of the subsidiary's plant, making it 212,-440 sq ft, and will bring its parking area to 67,000 sq ft. The company is also modernizing its **American Bosch Div.** at Springfield, Mass., and is moving the general office staff of its **Arma Div.** from Garden City, N. Y., to Hempstead, N. Y., to make room for more military work in the former city. Of its increased defense backlog of $195 million, a substantial portion is due to additional orders for the B-52 fire control system.

▶A new building (50,000 sq ft) for **Gulton Industries, Inc.**, in Metuchen, N. J. The additional research, engineering, and testing facilities will serve Gulton's five associated companies.

▶An electrical equipment assembly plant (31,000 sq ft) in Atlanta, Ga., for **Square D Co.**'s regional headquarters offices.

▶An electronic plant (150,000 sq ft) in the St. Petersburg-Clearwater area of Florida for **The General Electric Co.** The X-Ray Dept. will operate the plant, whose 600-700 employees will produce electronics equipment for **Sandia Corp.** of Albuquerque, N. M., prime contractor to the AEC.

▶A new facility (Plant No. 6) in Grand Rapids, Mich., for **R. C. Allen Business Machines, Inc.**, to increase production of damped rate gyros and turn and bank indicators.

▶Among recent acquisitions: the television and radio operations of **Raytheon Mfg. Co.** by **Admiral Corp.** —the two Chicago plants, inventory, and equipment to be known as Admiral's **Belmont Div.**; **Wm. I. Mann Co.** (precision optical components for scientific and military instruments) by **Texas Instrument, Inc.**; **Isotope Specialties Co., Inc.** (tagged chemicals for industrial and investigative procedures) and **Central Sales & Mfg. Corp.** (electron tubes, leak detection systems, electronic test equipment, transistor circuitry, microwave devices), both by **Nuclear Corp. of America, Inc.**, which will operate the latter acquisition as a wholly-owned subsidiary to be known as **Central Electronic Manufacturers, Inc.**; **Technical Electronics Corp.** (synchronous motors, system analyzers, packaged electronic circuits, precision measuring equipment) by **Consolidated Electronics Industries Corp.**; **Bennett Products Mfg. Co.** (glass-on-metal hermetic seals, insulators, switches, and connectors) by **Farnsworth Electronics Co.**, which will operate the Palo Alto, Calif., concern as a **Pacific Div.**; and **Micamold Electronics Mfg. Corp.** (military, television, and industrial capacitors) by **General Instrument Corp.**


Rufus Oldenburger


W. C. McFadden


Bernard Bernstein


W. W. Finke


G. A. Crowther


R. M. Soria

Important Moves By Key People

▶**Rufus Oldenburger**, an authority in mathematics and automatic controls who has combined careers in industry and education, will join the Purdue University faculty this fall as Professor of Engineering Sciences and Mechanical Engineering. Director of research of Woodward Governor Co. since 1954, Oldenburger joined the company as chief mathematician in 1942, while he was teaching at the Illinois Institute of Technology. When he accepted a full-time position at Woodward Governor in 1949, he gave up the chairmanship of the DePaul mathematics department. He organized the 1954 ASME Frequency Response Symposium, the second international conference on automatic controls.

▶**William C. McFadden** was appointed executive vice president of Hycon Mfg. Co., of which he previously was vice president and general manager of the Camera & Instrument Div. A former engineering supervisor for Walt Disney Productions, McFadden came to Hycon in 1949.

▶Central Electronic Mfrs., Inc., which recently became a subsidiary of the Nuclear Corp. of America, has appointed **Bernard Bernstein** chief engineer of its Electronic Tube Div. Bernstein formerly managed the Large Transmitting Tube Dept. for Amperex Corp.

▶Datamatic Corp., a subsidiary of Minneapolis-Honeywell Regulator Co. and Raytheon Mfg. Co., has named **Walter W. Finke** as its president. Finke, who was vice president and general manager, succeeds **John J. Wilson**, who continues as a director. Previously an executive of M-H, Finke is a former president of the U.S. Junior Chamber of Commerce.

▶**George A. Crowther**, holder of numerous gunfire control patents, was named chief engineer of Ford Instrument Co., Div. of Sperry Rand Corp. He has been with Ford Instrument since 1928, and was most recently engineering director for marine equipment, doing primarily Naval Ordnance work on gunfire control computers, selective range plotters, cam mechanisms for ballistic computers, and related devices.

▶Amphenol Electronics Corp. has promoted **Rodolfo M. Soria** to vice president of engineering. Formerly director of engineering, Soria has been with Amphenol since 1946. He is a member of the Advisory Group on Electronic Parts, consultants to the Defense Dept.

▶Minneapolis-Honeywell's newly-created position of vice-president in charge of engineering has been filled by **Glenn E. Seidel**, who was formerly

vice-president in charge of engineering in the firm's Minneapolis plants.

▶ The new Microwave Physics Laboratory of Sylvania Electric Products, Inc., will be headed by **Osmund T. Fundingsland. Arthur L. Aden** has been named the laboratory's assistant manager. Both Fundingsland and Aden have been directing research in Sylvania's Electronic Defense Laboratory since 1953.

▶ **George J. Mueller**, guided missile expert, has been named chief engineer of the Technical Products Div. of Packard-Bell Co. Mueller, who most recently headed the Test Support Dept. of Ramo-Wooldridge's Guided Missile Research Div., was head of the Physical Research Laboratory at Picatinny Arsenal. Later, he was an AEC consultant at Los Alamos and supervisory physicist at the Air Force Missile Test Center.

▶ **Frank A. Votta Jr.** has rejoined Hunter Spring Co. as chief engineer after two years with Philco Corp.

▶ **H. N. Muller Jr.** has been appointed chief engineer of Canadian Westinghouse Co., Ltd. Muller was formerly assistant to the vice-president, apparatus products, of the parent Westinghouse Electric Corp. Between 1947 and 1949 he was manager of the Educational Dept., where he was responsible for all Westinghouse graduate-level programs.

▶ Fenwal, Inc., has appointed **E. Sohier Welch** chief research engineer. Welch, who was head of the applied physics department of the National Research Corp., worked on radar countermeasures in Harvard's Radio Research Laboratory during the war. At the same time, **James R. Keough**, previously manager of personnel, purchasing, and production, has been named manager of manufacturing. **Robert S. Goodyear** is the new president of Fenwal's newly-organized subsidiary, Fenwal Electronics, Inc., which manufactures thermistors. He worked on thermistor production for Western Electric Co.

▶ **John C. Koch**, vice-president and general manager of Conoflow Corp., was elected president of the Fluid Controls Institute for 1956-57 at the Institute's recent annual meeting.

▶ **Sava Sherr**, former president of Stanley Industries, Inc., was recently appointed chief mechanical engineer of International Resistance Co. Sherr has been an engineering consultant to UNRRA's Agriculture Div and a member of the Pratt Institute faculty.

▶ A measurement and microwave

specialist has been appointed chief engineer of Sperry Gyroscope Co.'s Microwave Electronics Div. He is **Hugh E. Webber,** promoted from his post at the head of a microwave and electronic equipment engineering department, which he organized in 1948.

▶ Two new Cutler-Hammer vice-presidents have been named. **W. F. Lent** was appointed vice-president in charge of manufacturing and **R. A. Millermaster** vice-president in charge of development. Both men have been with C-H for many years. Lent's latest position was works manager, while Millermaster's was manager of development.

▶ **C. E. Gumbert Jr.** has been appointed chief engineer of Elbeeco, Inc., a subsidiary of Aeroquip Corp. He was formerly with the parent company's quality control dept. At the same time, **Mathias A. Gatzweiler** was selected as Elbeeco production control manager.

▶ **Alfred F. H. Bischoff** is the new manager of the Coolidge Laboratory, largest x-ray and electron-beam developmental lab in the world, which is part of General Electric's X-Ray Dept. He succeeds **Robert F. Wilson,** who has been given a special assignment. Bischoff has designed Loran equipment, adapted the British IFF (Identification, Friend or Foe) system to American use, designed the radio frequency power supplies for 70-million and 180-million volt synchrotrons, and directed the development of the fastest acting known relay (which operates in 0.00001 sec).

▶ **Robert J. Bibbero** has left his job as chief development engineer of Hillyer Instrument Co. to take special assignments in automation, control systems, and weapons systems from Bulova Research & Development Laboratories. He has developed a number of digital systems for automatic control of machine tools and speedy handling of business data.

▶ **Sidney L. Simon,** appointed director of applied research at the Research and Advanced Development Div. of Avco Mfg. Corp., is a former temperature pile problems specialist. He recently completed work as a nuclear scientist in General Dynamics' Project AID.

▶ **William Shockley,** transistor pioneer and director of the Shockley Semiconductor Laboratory of Beckman Instruments, Inc., was awarded an honorary degree of Doctor of Science by Rutgers University at its June commencement exercises.

▶ Consolidated Diesel Electric Corp. has appointed **Louis B. Haberman** as general manager of its Test Equipment Div. He was formerly a sales engineer with Greer Hydraulic, Inc.

ABSTRACTS

Servo Compensator

From "A Time Dependent Nonlinear Compensating Network" by J. C. Clegg, University of Utah. AIEE paper 56-778, presented at AIEE Summer and Pacific General Meeting, San Francisco, June 25-29, 1956.

In the April issue of CONTROL ENGINEERING, T. M. Stout concluded his article on "Nonlinearity in Control Systems" with this statement: "The theory (of programmed controllers) does serve, however, as a basis for the design of practical systems with very near optimum response, using simplified equipment whose performance approximates the ideal". The nonlinear compensating network described by Clegg falls directly into this category of simplified equipment, for here a simple combination of resistance, capacitances, and diodes improves performance of both linear and nonlinear servos.

The basic circuit shown by the solid lines of Figure 1 is inserted in the servo between the error signal

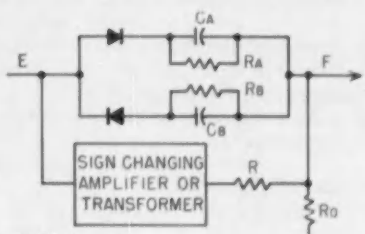


FIG. 1

and the uncompensated servo. Disregarding for the moment the sign changing amplifier and R, the circuit operates as follows: with a positive error voltage applied to the system input, the upper diode conducts and a voltage starts to build up across C_A. But at the instant of application the entire error voltage appears across R. Output voltage F causes the servo error to diminish. Thus, as time progresses, the error voltage decreases while the voltage across C_A increases.

Eventually, both voltages are equal, the diode stops conducting, no torque is applied to the servo output, and the servo flows down under the influence of its inherent damping. Thus the servo approaches zero error.

Should the error not become zero as a result of output coasting, the discharge of C_A through R_A means that the diode will eventually conduct again and jog the output further toward zero error. This continues until the system is nulled.

However, if the output overshoots during coasting, the error voltage becomes negative and the lower diode conducts. Circuit action similar to the foregoing obtains, but the correction is in the reverse direction.

This circuit works not only in dc servos, but also in servos where the error appears as a modulated alternating voltage. "The behavior of the network toward such a voltage is essentially the same as has been described except that the upper diode conducts during the positive half cycle of error voltage and the lower diode conducts during the negative half cycle".

If the inherent damping is not sufficient to bring the output to zero in a reasonable amount of time and without excessive overshoot, the circuit may be modified by adding to it the sign changing amplifier and R, as shown by the dashed lines in Figure 1. These additional components provide additional damping to the system. "As long as either of the diodes is conducting, the sign changer is relatively ineffective, because the impedance of the diodes and capacitors is made much lower than the resistance R. However, when the diodes are not conducting, the sign changer applies to the output terminal of the network a voltage that is opposite in polarity to the error voltage, thus causing the output torque to reverse, decelerating the controlled quantity more rapidly than could be done by inherent damping alone. The system would now be unstable . . . if it were not for the fact that the capacitors discharge at about the same rate that the error is reduced. Thus, by the time the controlled quantity has reached the null point, the capacitors are essentially discharged, allowing the diodes to conduct if necessary to override any negative error signal from the sign change".

Typical circuit components are: $R_A = R_B = 5$ megohms, $R_o = 0.25$ meg-

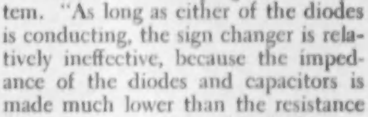


FIG. 2

ohms, $R = 13$ megohms, $C_A = C_B = 0.05$ microfarads. A 6H6 vacuum duodiode was used, and the sign changing amplifier (which could be

a transformer) had a voltage gain of two.

Just how well this circuit operates is typified by the results shown in Figure 2. The input to the system is a step change. Curve A shows the response to the uncompensated servo; *B* shows the response of the same system with the compensating network operating and the forward gain increased; and, for comparison, *C* shows the response of the original system (uncompensated) but with the gain reduced to eliminate overshoot.

Concentration Control

From "Evaporator Concentration Control By Boiling Point Rise" by W. S. Sharshon, Minneapolis-Honeywell Regulator Co., Brown Instruments Div. Paper presented at the American Chemical Society Delaware Valley Regional Meeting, Feb. 16, 1956.

An evaporator process that has a high enough boiling point rise (5 deg F or more) can be automatically controlled for uniform product concentration with standard instrumentation. The control of concentration by boiling-point-rise measurement assures accuracy and is simple and maintenance-free.

"Boiling point rise is defined as the difference between boiling point of a solution and the boiling point of the pure solvent at the same pressure. . . . Since BPR is a function of the concentration of the solute, this measurement can be used to determine and control product concentration where an evaporator process shows a sufficient boiling point elevation".

The method involves the measurement of two temperatures (the boiling liquor in the evaporator and the reference). The relatively small difference in magnitude between the temperatures means these primary measurements must be precise if an accurate determination of the difference temperature is to be made. The author recommends using an electronic potentiometer to obtain the required accuracy. The pot would operate from two differentially-connected resistance temperature detectors, properly located.

Sharshon describes the construction of an auxiliary chamber, which attaches to the evaporator and permits an accurate and stable reference temperature. "Thus, the chamber removes the superheat present in the feed steam and condenses some of the vapor. The resulting temperature is that of saturated steam (or boiling water) at the evaporator operating pressure, which is the reference temperature required in Boiling Point Rise determination". One detector measures the temperature in the reference chamber, and the other measures the temperature near the bottom of the evaporator. Therefore, this detector is always covered with liquor.

An evaporator system normally has instrumentation to control liquid level and evaporator pressure, since control of these variables are essential to good performance. Figure 1 shows this basic instrumentation applied to the evaporator system. Also shown is the slight additional instrumentation required for the control of product concentration.

Calibration curves, obtained from data on the evaporator installation, correlate product concentration with boiling-point rise. Figure 2 shows a typical relationship of this nature, where organic acid is being processed in the evaporator.

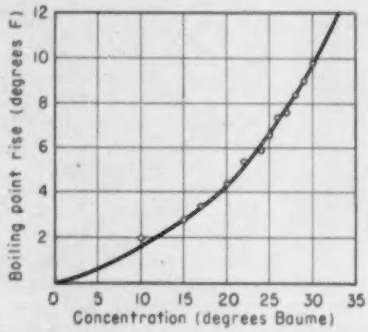


Fig. 2 Boiling point rise calibration curve

The control point of desired concentration is selected from the calibration curve and the system is started up. "In the initial stage of operation, the evaporator contents will be far below this point and the liquor will be retained and recirculated. As the desired concentration is reached, product will be drawn off continuously. Simultaneously, the liquid level controller will admit dilute feed to maintain liquid level".

A fully automatic continuous unit of this type has been installed. It controls product concentration to within 0.003 specific gravity units, and has operated trouble-free since installation.

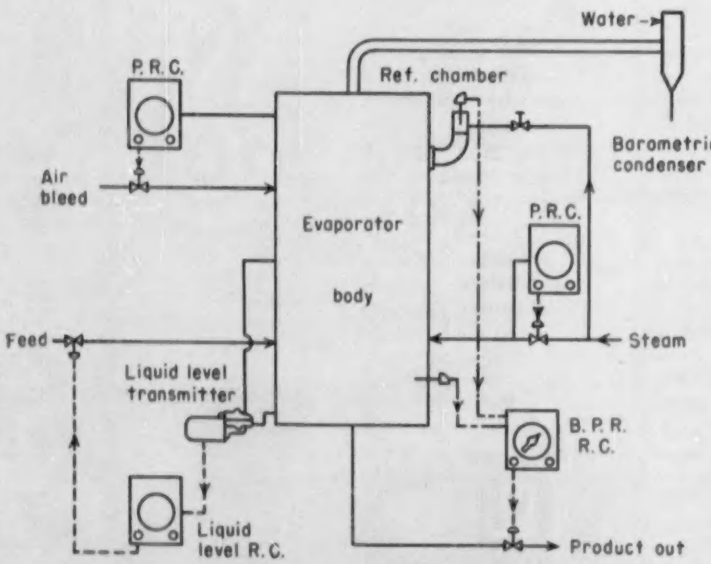


Fig. 1 Basic evaporator control system

Mechanical Translation

From "Some of the Engineering Aspects of the Machine Translation of Language" by R. E. Wall Jr., University of Washington. AIEE paper 56-693, presented at the AIEE Summer and Pacific General Meeting, San Francisco, June 25-29, 1956.

"There appear to be no insurmountable engineering problems in the realization of a mechanical translation machine." Wall makes this statement toward the end of his paper, thus concluding a thorough review of the engineering and linguistic problems of transforming intelligence from a "source" language to intelligence in a "target" language.

Recent advances in computer technology make possible a mechanical translator that could be competitive with a skilled human translator. Although it is unlikely that the machine could match the human translator in the matter of quality, the machine translator is superior in speed and expense (a lower cost per word of translating).

The author equates, admittedly on an arbitrary basis, machine translations to human translation to arrive at some idea of the relative speeds and cost. "Human translators will produce rough, understandable translations for a per-word cost of about one cent. This means that a two-hundred-fifty dollar per hour machine would have to produce about twenty-five thousand words per hour, or in round numbers about ten words per second in order to have the same per word cost."

The translation process for a machine requires four definite phases: encoding, memory search, logical operations, and decoding. Thus the machine language must be considered, as well as the two linguistic languages involved.

The two basic problems in encoding, then, are the selection of the optimum machine code and the transcription of printed text into this machine code. Each symbol should be of equal length, but of the least number of bits for economical storage in the machine. For instance, Russian requires 80 symbols (code groups) that include numbers, punctuation marks, and lower case and capitalized letters. A sample code given in the paper, applied to a random sample of Russian text, shows an average length per symbol of 5.23 bits. Normally, an 80-symbol combination requires a seven-bit code, so here the inherent characteristics of the language itself (such as the relative occurrence of symbols and no need for capitalizing certain symbols) allows a 25 percent savings in the storage capacity of the machine.

The make-up of the source language plays an important part in the permanent memory system of the mechanical translator. The machine must store all source language words and idioms, but so that the physical requirements of the memory portion of the machine may be reduced, it need not store internationals (words shared by the source and target languages). Other ideas for reducing the size of the memory (and hence the cost of the mechanical translator) are discussed: for example, the scheme for dissecting compound words.

The memory is essentially a dic-

tionary. "About 1200 words constitute approximately 40 percent of text material in most languages, so it would seem profitable to include these words of short length and very high probability of occurrence in a separate section of the memory. Then incoming text words could be compared with this small dictionary before comparison with the large memory. For German-English the dictionary requires the storage of about 40 megabits of information".

The design limits of the permanent memory are the maximum allowable access time and the maximum allowable size. The size depends on physical limitations, while the access time depends on the efficiency of the search routine. "Thus it is sometimes better to store more material in order to realize a more efficient search routine. The first criterion for determining the amount of material which must be stored in the memory system is necessarily the linguistic requirements of the problem". Other factors that affect access time to the memory are the size of storage, sequence of storage, and the method of coding the material.

Storage in the dictionary might be first on the basis of word length and then alphabetical; or perhaps first on the basis of grammatical type and then alphabetical; or completely alphabetical". . . . Complete alphabetization has been one clearcut advantage over all other methods; each word then has a unique address in the store determined by one criterion alone—the spelling of the word."

Next, Wall covers the logical operations required to obtain the context of meaning rather than a word-for-word translation. This means attaching a linguistic "tag" which denotes grammatical information about the word. "The logical operations are probably the most important area for contemporary research".

Programming a Borer

From "A Numerically Controlled Jig Borer" by J. J. Jaeger, Vice-president, Pratt & Whitney Co., Inc., Paper 24T12, delivered at the Tool Engineering Conference, March 20, 1956.

The jig borer is ideal for numerical control because it is basically conceived for measuring systems that permit high accuracy of tool or workpiece positioning. Its heart is its measuring system. In this case, a basic measuring bar having

1-in. spacings along its length. These spacings are electromagnetically sensed by a head that indicates its null position electrically. The bar can be built to a high degree of precision in long lengths. Present techniques permit bars up to 80-odd in. long with a maximum inch-to-inch and accumulated error of less than 0.000050-in. The bar is made of stabilized steel having the same coefficient of expansion as the components of the machine.

The sensing mechanism operates through an air gap so that there is no wear due to the rubbing or contacting of adjacent surfaces. Since there is no mechanical backlash to be considered, positional errors in either direction can be detected readily. Readings can be taken remotely, so the bar need not be accessible to the operator and can be placed at its optimum position.

To split each inch into its ten thousand parts, the sensing head (which has virtually no electromagnetic force due to the low flux densities) is moved by a precision screw having 1-in. travel. This screw is required to carry only the load of the sensing head and is manufactured to a high degree of precision. In addition, it is equipped with a corrector bar compensating for the remaining inaccuracy. Errors in positioning of the sensing head do not exceed 0.000010 in. Motive power to the table is completely independent of the measuring system. No wear can be expected in the measuring system during its anticipated life. An additional advantage lies in the fact that zero can be arbitrarily established at any position along the table and measurements can be taken either negatively or positively, making it possible to dimension drawings from any base lines without requiring operator to establish a base line by computation.

Information to the machine can be presented either through an operator's keyboard having dials (which can be pre-set to the desired dimensions) or through a tape reader, which will take its information from holes prepunched in a tape. The information presented to the machine is broken into several groups for each of the X, the Y, or the other coordinates required. This digital information is converted into electrical analogs which control the several elements of the system. Thus, on the basis of given information, an analog voltage representing the first three digits of the system is applied to the control to establish an approximate position of the slide. Simultaneously, two analog voltages, representing the decimal fraction of the inch for the micrometer drive, are applied to position the sensing head precisely to the fractional inch requirement.

NEW BOOKS

Higgins on a Compendium . . .

INDEXBÜCHEN DER TECHNIK, BAND REGELUNGSTECHNIK. *Published by Dokumentation der Technik, München 8, Zweibruckenstrasse 24, Germany. Price: 82 DM (approx. $19.50).*

These ring-binder summaries of 1,450 articles by 900 authors are representative of more recent consequential literature on the theory and application of automatic control. The stress is on European literature, particularly German writings.

The uses of this work are manifold: for the teacher of control engineering, clues to a great volume of theory not contained in published textbooks; for the control engineer interested in design or development, many possibilities or applications that could prove of value in his work. The volume belongs in the libraries of all engineering colleges, on the reference shelves of all industrial and/or research organizations concerned with automatic control, and in the personal collections of those engineers most anxious to keep abreast of the rapid advance in modern control engineering.

. . . on Russian Control . . .

ELECTRIC AUTOMATIC CONTROL *(in Russian). A. G. Ivakehenko. Published by Gosudarstvennoe Izdatel'stro Tehknickeskoj Literatury URSS, Kiev, Russia.* Vol. 1, 290 *pp.*, Vol. 2, 218 *pp.*

This two-volume book is intended for engineering students (primarily at the graduate level) and for practicing engineers. As such, there is little in it that cannot be found in one of the major tests written in English, such as the two-volume work by Chestnut and Mayer.

Volume 1, "Fundamentals of the Theory of Automatic Control", opens with a chapter on basic notation and definitions. Subsequent chapters are devoted to formulating the differential equations of performance of various automatic control systems; determining the solutions for transient and steady-state operation of a system; and determining the nature of the stability of a system.

Volume 2, "Investigation of Automatic Control Systems by Use of Harmonic Functions", is a well-integrated account of frequency-response analysis. Frequency-response determination of stability, compensation, response to both command and perturbing inputs, and other basic aspects of performance are emphasized. A particularly interesting account is given of the calculation and improvement of relay-type servomechanism performance.

The writing is lucid and the detailed theoretical sections are buttressed by well-selected illustrative examples. The chapters on relay-type servomechanisms (a subject on which more has been written in Russian than in English) are particularly good. The teacher or engineer interested in the fine detail of control theory will find much to be gained by a careful reading of this book.

. . . on Numerical Analysis . . .

MÉTHODES DE DIFFÉRENTIATION ET D'INTÉGRATION NUMERIQUES: APPLICATIONS *(Methods of numerical differentiation and integration, with examples). A. Ziller, Professor of Engineering, University of Strasbourg, France. 150 pp. Publications Scientifiques et Techniques du Ministère de l'Air, No. N.T. 50. Sold by Au Service de Documentation et D'Information Technique de l'Aéronautique, Magasin C.T.O.: 2, Avenue de la Porte-d'Issy, Paris (15e), France.* 1500 francs. (approx. $4.00).

This clearly-written and well-organized work describes the author's own specialized procedures of numerical differentiation and integration, which complement, rather than parallel, more familiar procedures advanced in books on numerical analysis. Therefore, considering the amount of numerical analysis that attends certain phases of modern control engineering (e.g., computing frequency response from experimentally determined transient response and vice-versa), this volume should prove of particular interest to the control or computer engineer concerned primarily with the analysis.

The preface presents the general philosophy of numerical analysis and Ziller's particular approach; a foreword notes the origins of Ziller's interest in numerical differentiation and integration; and an introduction, delineates the scope and organization of the text. Nine chapters form its two major parts.

The first part, devoted to numerical differentiation, has five chapters. Chapter I, "Detail Relative to Development of a Function in a Taylor's Series", advances the basic theory of expansion in a terminated series of n terms with parameter $0 \leq \theta \leq 1$; a means for accurately approximating θ; and formulation of an equation for computing the magnitude of the error resulting from use of an approximate value of θ. This theory is basic to the remainder of the work.

Chapter II, "Numerical Differentiation", derives three-interval and four-interval equations for obtaining the first five or six derivatives of a function. These equations are used in Chapter III, "Interpolation", and Chapter IV, "Extrapolation", to obtain equations for both direct and inverse interpolation and for extrapolation—using equal intervals. If the given values of a function are not equally spaced, it is necessary to determine from them a set of corresponding equally spaced values. The procedure for doing so is found in Chapter V.

The second part, devoted to numerical integration, contains four chapters. Chapter I advances two equations for effecting numerical integration; one is based on the fact that the derivative of the integral of a function is the integrand of the integral, while the other is obtained by expanding the integrand in a terminated Taylor's series. These equations form the basis for Chapter II, "Calculation of a Definite Integral", which covers transformations of intervals and functions to achieve a normalized unity interval, and the integration of trigonometric, exponential, square-rooted, and combined integrands. In turn, the equations for single integration provide the numerical procedures for double integration in both rectangular and polar coordinates (Chapter III). Chapter IV, "Solution of Differential Equations", details a general scheme for differentiating a given equation to obtain successive derivatives of the function sought and substituting these in a terminated Taylor's series to obtain numerical values of the desired function. Specific application of this scheme is demonstrated for linear equations of the first and second order.

This book is lucidly written. Each point of theory is given clearly and in full detail. Each procedure developed is supported by corresponding development of associated equations enabling calculation of the error stemming from its use. (The possibility of precise calculation of a pertinent error is the central feature of the author's work). Finally, each of the numerous procedures developed by the author is detailed by solution of from one to four illustrative examples, chosen to show both the advantages of a procedure and, when they occur, its shortcomings. The reviewer recommends this book to anyone concerned with numerical computation—whether in control or computer engineering, data processing, operations research, or programming.

. . . and on Automation

The Automatic Factory. 228 pp. *Published by E. and F. N. Spon, Ltd., 22 Henrietta Street, W.C. 2, London, England. 30 shillings (approx. $4.20).*

The Challenge of Automation. 77 pp. *Published by Public Affairs Press, Washington, D. C.*

The Automatic Factory: a Critical Examination. S. A. June *and Associates. 88 pp. Published by Instruments Publishing Co., Pittsburgh, Pa. $2.00.*

Industrielle Automatisierungstechnik *(Industrial Automation Engineering).* W. Hornauer. *160 pp. Published by VEB Verlag Technik, Berlin W8, Germany. 15 DM (approx. $3.50).*

The Automatic Factory is a hard-cover edition of the "Report of the June 1955 Margate Conference of the Institution of Production Engineers". These papers were reviewed in the February 1956 issue of Control Engineering.

The articles in *The Challenge of Automation*, essentially the proceedings of the National Conference on Automation, nicely complement the British contribution. The latter papers deal primarily with the socio-economic consequences of automation, considering the effects of large-scale use of highly mechanized or full automatic equipment on workers, standards of living, and the national economy. Much of the discussion is conjectural rather than factual; the control engineer may therefore read it with reservation.

The Automatic Factory: A Critical Analysis reports on a look into control by a group of Harvard Business School students. They tried to "give a down-to-earth answer to the question, 'What is, and what can we expect from, the Automatic Factory?'" The report discusses difficulties to be overcome before 100 percent automation can be achieved, costs, the social and economic significances of automation, and associated topics; and gives detailed accounts of four instances of automation. The reviewer doubts if this study provides a definitive answer to "the great contemporary question", but he found the economic and financial discussion and detailed case studies of great interest.

The actual engineering and implementation of automation is the theme of the German book. *Industrielle Automatisierungstechnik* gives an excellent account of the rapid growth of

automation in Eastern Europe and of the engineering techniques upon which the growth has been based. Many working installations of interest to the design-oriented control engineer are shown in the 139 figures.

Briefly Noted by Higgins

MACHINE LITERATURE SEARCHING. *J. W. Perry, A. Kent, and M. Berry. 162 pp. Published by Interscience Publishers Inc., 250 Fifth Avenue, New York, N. Y. 1956.* $4.00.

This book will prove of interest to anyone who is continuously searching large volumes of more or less pertinent data for specific details on one area of knowledge. It gives a complete account of different means and procedures for automatically combing large reservoirs of published information—a rather unique form of data processing.

Thomas J. Higgins
Professor of Electrical Engineering
University of Wisconsin

Treatise on Automation

AUTOMATION — FRIEND OF FOE? *R. H. Macmillian. 100 pp. Published by Cambridge University Press, 32 E. 57th St., New York,* 1956. $1.95.

Macmillian makes quite a switch here from his highly technical *Theory of Control* (Cambridge University Press, 1951). In a few hours' reading time, he paints a clear picture of automation today, its origin, and its possible consequences.

He leads off with a brief history of automatic controls and their recent rapid development, pointing out basic differences between open and closed control systems and explaining underlying principles with examples of typical application.

In touching on the growth of automation in manufacturing and industrial processes, the author outlines the basic problems facing designers of control equipment. The increased demand for better response and higher accuracy of control serves only to compound these problems.

Recent developments in the computer field compel him to predict some interesting changes. "It seems certain that the routine clerical worker will finally disappear long before his opposite number in the workshop vanishes."

Besides giving a fine treatment of the technical problems, Macmillian does a commendable job of pointing out the economic problems of automation today. As for the future, he believes that ". . . engineers ought to be alive to the social and economic implications of the machines and processes with whose design and operation they are concerned". For these thoughts alone, the book is worthwhile reading.

A brief summary of related works on the subject of automation and automatic control systems follows the last chapter.

Briefly Noted

HOW TO FIND A BUYER FOR YOUR INVENTION. *V. D. Angerman, Editor and Publisher, "Science and Mechanics Magazine", 186 pp. Published by Science and Mechanics Publishing Co., Chicago.* $2.95.

The new thing here is a list of 140 manufacturers who are definitely in the market for inventions. They are listed and indexed in four ways: by inventions wanted; materials available, equipment and processes available, and consulting development, and marketing facilities. The book also tells how to contact the proper executive in each concern.

The greater part of the text gives fresh treatment to such things as marketability and patentability of an invention, patenting procedure, rights granted by patents, selling the patent vs. manufacturing, etc.

PROCEEDINGS: AUTOMATIC DATA PROCESSING CONFERENCE. *Edited by Robert N. Anthony. 194 pp. Published by Graduate School of Business Administration, Harvard University, Boston, Mass. Paperbound.* $3.50.

Three hundred top executives and controllers attended this conference last September to hear how automatic data processing aids in the formulation of administrative decisions. The subjects covered by the 12 talks included principles and techniques of data processing, problems in determining the utility of automatic data processing, centralized vs. decentralized organization, standard and special purpose equipment, selection of applications, case studies in processing payrolls and production planning, and operations research. The book also contains the discussions that followed each session.

WHAT'S AHEAD: MEETINGS

AUGUST

National Telemetering Conference, Sponsored by Institute of Radio Engineers, American Institute of Electrical Engineers, Instrument Society of America, Institute of Aeronautical Sciences, Biltmore Hotel, Los Angeles. Aug. 20-21

Western Electronics Show and Convention (WESCON), Institute of Radio Engineers, Pan Pacific Auditorium and Ambassador Hotel, Los Angeles. Aug. 21-24

The Association for Computing Machinery, 11th Annual Meeting, University of California, Los Angeles Association address: Box 3251, Olympic Station, Beverly Hills, Calif. Aug. 27-29

Sixteenth Annual Appalachian Gas Measurement Short Course, West Virginia University, Morgantown, W. Va. Aug. 27-29

Third Annual Symposium on Digital and Analog Computers, Denver Research Institute and National Simulation Council, University of Denver, Denver, Colo. Aug. 30-31

SEPTEMBER

Institute of Radio Engineers, Information Theory Symposium, Massachusettts Institute of Technology, Cambridge, Mass. Sept. 10-12

American Society of Mechanical Engineers, Fall Meeting, Denver, Colo. Sept. 17-20

Instrument Society of America, 11th Annual Instrument-Automation Conference and Exhibit, N. Y. Coliseum, N. Y. Sept. 17-21

Industrial Electronics Conference (no exhibits), American Institute of Electrical Engineers, and Institute of Radio Engineers, Hotel Manger, Cleveland, Ohio. Sept. 24-25

OCTOBER

National Electronics Conference, Institute of Radio Engineers, American Institute of Electrical Engineers, Hotel Sherman, Chicago. Oct. 1-3

American Institute of Electrical En-

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OCTOBER

National Electronics Conference, Institute of Radio Engineers, American Institute of Electrical Engineers, Hotel Sherman, Chicago. Oct. 1-3

American Institute of Electrical En-

(*Continued from preceding page*)

gineers, Fall General Meeting, Hotel Morrison, Chicago. Oct. 1-5

Conference on Magnetism and Magnetic Materials, American Institute of Electrical Engineers, Institute of Radio Engineers, Hotel Statler, Boston. Oct. 16-18

National Conference on Industrial Hydraulics, Annual Meeting, Hotel Sherman, Chicago. Oct. 18-19

Institute of Radio Engineers, Third Annual East Coast Conference on Aeronautical and Navigational Electronics, Fifth Regiment Armory, Baltimore, Md. Oct. 29-30

CONTROL PULSES

DATING THE TWINKLE

Cambridge University's Edsac computer, which for a year now has been calculating the age of the galaxy in which the earth spins, has come up with an answer: 6.5 billion years. Fred Hoyle, a British cosmologist, and C. B. Haselgrove, a mathematician, worked on the project, which began with a "model" star whose age was determined by four sets of differential equations relating to its mass, radius, pressure, etc., and its brightness and surface temperature. These characteristics were then used figuring the age of every other star in a cluster of 100,000.

STOREHOUSE OF KNOWLEDGE

A dissenting opinion on automation, particularly magnetic-tape information storage, has been made by U. of California Librarian L. C. Powell. He wants no part of it in his bailiwick, castigating "analysis probers and planners who long to de-emphasize books, mechanize the library, and change its name to 'materials center'." He is worried about "dissemination of knowledge by machine" and feels that the recording and transmission of knowledge can still be done better by the book than by any other known means.

PROGRAMMED PARTIES

The first fully automatic bar has been built! General Control Co.'s assistant advertising manager, Huntly Briggs, designed the machine, which is operated by controls set for liquor selection, mixer, and liquor proportion. To guard against over-indulgence, the machine "fails safe" if more than 50 percent of a drink is made of whiskey.

DRIVING AWAY CUSTOMERS

The new automatic washing machines were going for as low as $10 down and $2.50 a week, and every buyer could cart his purchase away in a free used car. Thus, the Beacon Co., an appliance store in Akron, Ohio, not only had customers beating a path to its door, but drove them away, too.

AUTOMATION ON REELS

By putting a "pinhead" to work for him, the movie-house projectionist of the future may be able to saunter into the balcony to enjoy the show in com-

fort. The pinhead, a basic component in a device recently tested in a British cinema, touches off the various steps in movie-projecting by actuating associated micro-switches located behind a rotating drum. The only function it does not control is machine changeover. This is governed by electricity-conducting lacquer applied to the tail of the film and sensed by detecting rollers.

WATER TO THE RESCUE

The discovery by Westinghouse atomic scientists that as water expands under heat, it knocks neutrons out of a reactor core, has suggested a simple way to control the reactor. Up to now, chain reactions had to be broken up by relatively rare, expensive, and hard-to-work materials like hafnium metal. But a recent study of the steam phase of reactor kinetics has convinced scientists that steam control rods can do the job more simply and less expensively by letting extra neutrons "leak" out of the core.

COMPONENTS AT WORK

The best way to take the "awe" out of automation is to show it as it really is—several precise, usually small components, operating on the feedback theory. That's just what The Servo Systems Co. of Newark, N. J., has done, by developing what it calls a "Servo-Kit", which contains a servo amplifier, two Barber-Colman motors, and a two-volume training course. The whole thing sells for less than $100—$98.50, to be exact—and weighs only 22 lb. A pre-amplifier and a stabilization unit are available for more precise or higher-gain applications.

OFFERS AIR FORCE TALENT

One way to alleviate the shortage of secondary-school science teachers is to send technically-trained Air Force personnel into high-school classrooms. General Nathan F. Twining, Air Force Chief of Staff, believes. In a speech at an armed forces luncheon in Detroit, Twining said that "inadequate numbers of technically-trained people could take on the nature of a true national emergency, if it has not already" and that "just as the Air Force has stepped in temporarily to aid in other emergencies, we are now offering our help in this one".

PAINTING WITH ELECTRONS

Two (or more) cars in every garage may be a fact if Ford Motor Co. perfects a new automotive paint. A few passes with an electro-magnetic gun and the neutral white changes to any color desired.

A MESSAGE TO CONTROL ENGINEERING's SUBSCRIBERS AND ADVERTISERS:

"HOW TO FOLLOW THE STEPS In Control Systems Engineering"

The theme of Control Engineering's September Issue—the most valuable single magazine issue ever published for the control systems engineering field . . .

Valuable to Our Subscribers: For the first time anywhere, in book or magazine, all the phases of control systems engineering will be presented as an integrated unit. In September CONTROL ENGINEERING, each segment of control work will be related to the others as logical steps. The issue will be, in effect, an authoritative source book, an omnibus, a "consultant-in-print" for the control engineer. It will, beyond question, become a part of the control engineer's basic reference literature.

Valuable to Our Advertisers: This will be "the book" on control systems engineering, A to Z—from machine or process analysis, through design, to the specification of system components. You're surely aware how eager control men are for information that advances "the art." They want to know "how to do it," and they want to know just as urgently "what to do it *with*." Your advertising will give them detailed facts on how your products "fit the loop," . . . what particular advantages those products have in helping the control engineer solve a particular control problem. In an area where brand preferences are still unformed, you have an exceptional opportunity, in a basic reference such as this, to influence those preferences in your favor. The earlier you establish such preferences the stronger they will grow. The scope of the articles in the "Follow-The-Steps" issue gives you a sound editorial premise for telling control engineers where you fit in.

What Are Those Steps the Issue Will Cover? There will be 11 major articles, covering over 100 editorial pages. They will start with "Why You Should Practice Control Engineering," and end with how to test the completed, installed control system. Each article will follow in logical progression.

Who Will Read this Issue? It will be read by more than 28,000 practicing control engineers. Our circulation department requires direct, confirmed evidence of job titles and responsibilities, before paid subscriptions are accepted. Subscribers are men who have proven they are entitled, as control engineers, to receive the publication. They've been rigidly screened as men who select, specify and buy the instruments, components and other equipment used in control systems. (In addition to regular subscribers, we're preparing for exceptionally large single copy sales.)

Who Will Write the Articles? The author of each of the 11 articles will be a respected authority in his special control area. Our editors have been rounding up these authors since last November, checking preliminary plans of the issue with them, correlating their ideas on how to integrate this presentation.

Who Started This Whole Project? A group we esteem highly—our readers. The men, who month in and out, apply CONTROL ENGINEERING's editorial content to their job problems. In traveling, in visits with their readers and contributors, our editors frequently ask, "What's the most urgent editorial job we should take on?" A frequent answer: "A story that ties together all the parts of control systems engineering . . . the Big Picture." Imposing as it was, our editors took the challenge.

Why Is It Timed for September? For one thing, September will be our second anniversary of publishing CONTROL ENGINEERING. For another, the editors decided the organizing and writing job would take a full 10 months. Thirdly: The ISA Show in September, at the Coliseum, New York. Looking ahead last November, the editors foresaw they could perform a genuine service in relation to this 11th Annual International Instrument-Automation Conference and Exhibit, by providing a unifying theme. They expect, very reasonably, that September CONTROL ENGINEERING will broaden the thinking of control engineers who attend the show. It will open their minds to control ideas and products beyond their immediate work horizons. CONTROL ENGINEERING's A-to-Z coverage will give control engineers an active interest in the broad range of the product displays they are exposed to at the ISA Show.

A Note About Copy: It's important in this September issue to register the entire scope of your company's activities. Present all the products and services your compony offers relating to instrumentation and control in wet process, machinery or airborne applications. We have sound evidence that our subscribers *do* like, and read, long articles and detailed advertising copy, when either is pertinent to the problems these men must solve. Take sufficient space to cover thoroughly your product specifications and application data. Our readers want all the product detail you can give them.

Closing for advertisers: August 1st

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A few openings have developed in our organization for well qualified engineers who can participate in and lead in these areas:

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P-2277, Engineering News-Record
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Classified Advertising Division
CONTROL ENGINEERING
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Plants and Laboratories at Endicott, Poughkeepsie, Owego and Kingston, N. Y., and San Jose, Calif.

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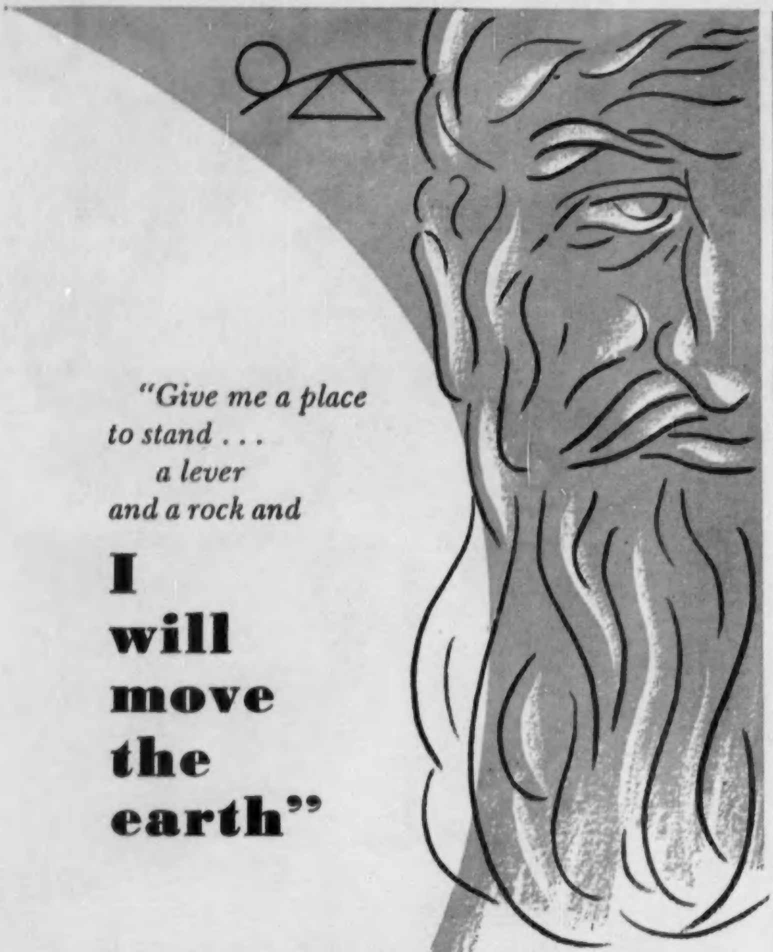

"Give me a place to stand . . . a lever and a rock and

I will move the earth"

Today, as in Archimedes time, many a scientist and engineer is stymied through lack of facilities for research, development and production of an "out of this world" idea.

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P-1210 Control Engineering
330 W. 42 St., New York 36, N. Y.

SALES and SERVICE ENGINEERS WANTED

Excellent opportunities for engineers with well established East Coast Industrial Instrument Manufacturer now expanding branch office coverage.
Electrical, Mechanical, or Electronic Engineers preferred.
Openings for Sales Engineers in St. Louis, Los Angeles, Cleveland, and Boston.
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Generous company paid benefits include hospitalization, pension, insurance, and vacation plans.

P-1917, Control Engineering
330 W. 42 St., New York 36, N. Y.

ENGINEER, E.E.

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Here's an opportunity for a creative engineer with 5 years experience and additional study in the field. Must have solid technical background plus ability to make sound engineering decisions.

Servomechanisms and associated components are treated as an art at General Electric's Naval Ordnance Department. Original contributions welcomed in design of technically advanced systems.

An outstanding feature is the opportunity GE will provide you to keep abreast of current developments in the field. This is only one of the professional advantages you will gain, in addition to personal recognition for work performed. Too, you will gain all advantages of one of the most progressive and comprehensive company benefit plans in industry, plus excellent salary, commensurate with experience.

Please send resume in confidence to:

Manager, Engineering Admin.
Naval Ordnance Department

GENERAL ELECTRIC
100 Plastics Avenue
Pittsfield, Mass.

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FOR ADVANCED WEAPONS SYSTEMS

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Carry your ideas through to final hardware and operational flight testing.

Perform creative system studies and instrumentation.

Apply the latest technological knowledge in such areas as:

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BALLISTICS RESEARCH • TELEMETRY

Salary—up to $12000
(Commensurate with experience)

Send resume in confidence to:

Manager of Technical Personnel, Dept. 674

ARMA

Division American Bosch Arma Corp.
Roosevelt Field **Garden City, L. I., N. Y.**

ASST. CHIEF ENGINEER
Controls Division

Present chief 62 years old, retiring soon. 700 man plant; products have unexcelled acceptance throughout U. S. Potential unlimited to creative engineer. Starting salary $12,000-$15,000. Employer pays agency fee & relocation cost.

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. . . because it could open the door to a lifetime job in a wonderful company

If you're an Electrical Engineer, with a high degree of skill and imagination in any of the twenty-odd fields listed right, we believe we can offer you the most promising opportunity in America.

Since 1940, Stromberg-Carlson's volume has increased *sixteen times*. In 1955, we became a division of the headline-making General Dynamics Corporation. Our future is as unlimited as humans can promise themselves—and *you* could well grow with us.

We are not looking for job-hoppers—but for men now stymied either by the limitations of a little company or the complexity of a giant. In any of the job classifications listed here, you'll find satisfaction and opportunity.

And you'll like Rochester—well-known for its grand schools, handsome residential sections and wide entertainment, vacation and cultural facilities. This firm's employee relations (including a liberal bonus plan) make it one of the state's preferred industries.

Write *today*—for an assured tomorrow!

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- Auto Radio
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- Countermeasures
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- Electronic Switching
- Infrared
- Intercom Systems
- Laboratory and Test Engineering
- Loudspeaker
- Magnetic Tape Recorders
- Microwave, communication
- Navigational Systems
- Radar
- Telephone Switching Technique
- Transistor Engineering
- Voice communication
- Writers—Bid Proposal
- Writers—Technical

Send your letter to Mr. Arthur N. Paul

STROMBERG-CARLSON COMPANY S-C
A DIVISION OF GENERAL DYNAMICS CORPORATION
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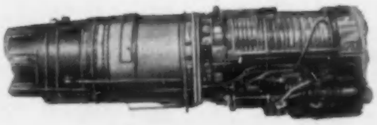
AC ELECTRONICS DIVISION

NEEDS HYDRAULIC RESEARCH ENGINEERS

To Develop TEST FACILITIES for Jet Engine Fuel Control Systems and Components.

Working with:
High Energy Fuels at Extremes of Temperatures and High Pressures



Test Stands

Environmental Test Cells

Remote Instrumentation

Servo Operated Afterburner Fuel Controls, Inlet Temperature and Turbine Speed Sensing Electro-Hydraulic Servo Controls.

Applicant should have B.S. Degree Plus 4-6 Years Experience Relative to Hydraulic Engineering, Valve Design, Hydraulic Servos, Instrumentation and Testing of Fluid Control Devices, or Other Associated Fields.—Write to Mr. J. Heffinger, Supervisor of Salaried Personnel

AC THE ELECTRONICS DIVISION

GENERAL MOTORS CORPORATION

MILWAUKEE 2, WISCONSIN also FLINT 2, MICHIGAN

INSTRUMENT ENGINEERS

Career opportunities in instrument engineering. Candidates considered with degrees in either Mechanical, Electrical or Chemical Engineering. Two to Five years' experience in process control instrumentation and/or application of pneumatic and electronic control equipment required.

Give full and specific details of education, experience, desired salary, availability date and references.

All inquiries will be considered promptly and held confidential.

ESSO STANDARD OIL COMPANY

Esso Research and Engineering Company

Employee Relations

P.O. Box 51 Linden, N. J.

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The successful applicant will be expected to have substantial experience in research, application, consulting, or development of techniques for measuring process variables.

NEW YORK CITY INTERVIEWS

Sun-Mon-Tues-Wed
Sept 16-17-18-19

For appointment, please call

Mr. J. C. Costello, Jr.
Circle 7-8051

Or you may send complete resume, including details of education and experience, to:

Mr. J. C. Costello, Jr.
Engineering Department

DU PONT

Better Things for Better Living
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E. I. du Pont de Nemours & Co., Inc.

Wilmington 98, Delaware

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R. M. H. BERG — **Advertising Sales Manager**
W. C. CARMICHAEL — **Production Manager**

ATLANTA 3:
William D. Lanier, 1321 Rhodes-Haverty Bldg., WAlnut 5778
BOSTON 16:
George S. Baird Jr., 350 Park Square Bldg., HUbbard 2-7160
CHICAGO 11:
John G. Zisch, 520 N. Michigan Ave., MOhawk 4-5800
CLEVELAND 15:
John C. Mitchell, 1510 Hanna Bldg., SUperior 1-7000
DALLAS 2:
Gordon L. Jones, Douglas Billian, 1020 Adolphus Tower Bldg., PRospect 5064
LOS ANGELES 17:
Gene A. Fruhling, 1125 W. Sixth St., MAdison 6-9351
NEW YORK 36:
Robert W. Obenour, 330 West 42nd St., LOngacre 4-3000
PHILADELPHIA 3:
W. F. Buehl, Architect's Bldg., 17 & Sansom Sts., RIttenhouse 6-6070
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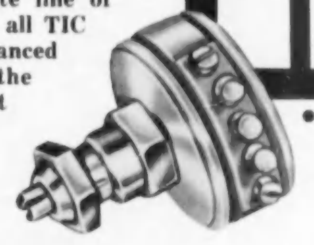
T. H. Carmody, R. C. Alcorn, 68 Post St., DOuglas 2-4600

THERE'S A Trimmer Potentiometer FOR EVERY APPLICATION

TIC manufactures in production quantities the most complete line of precision trimmer potentiometers in the industry. Common to all TIC trimmers is the unexcelled TIC quality construction and advanced design. The wide selection of sizes and shapes, in addition to the wide range of power and temperature capabilities, permit selection of units of maximum compatibility with a specific application.



The TIC Trimmer Potentiometer Line includes units from ½ inch to 1 inch in size . . . 50 to 100K ohms in resistance . . . −55°C to +145°C temperature range . . . power ratings up to 4 watts. Advanced mechanical design provides extremely precise, stable adjustments under all forms of adverse environmental conditions.

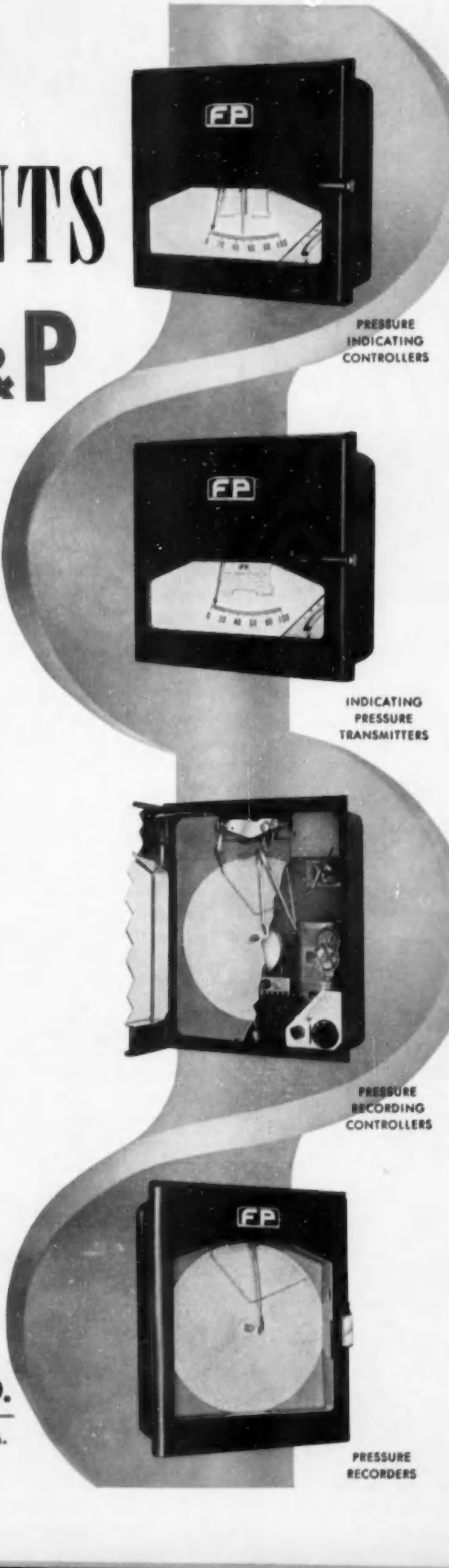
TIC was the originator of the high stability subminiature trimmer pots. For example the original metal-film potentiometer, the TIC RFT Metlfilm, represents the outstanding advance high stability trimmer potentiometer design. The RFT contains a resistance element of metallic film that provides infinite resolution for ultra-fine trimming. Compactness of the RFT permits stacking 7 to the square inch. Latest addition to the TIC Trimmer Line is the new low cost RWT which, like the RFT, provides adjustment by use of a 25-turn lead screw.

Complete information on the TIC Trimmer Potentiometer Line is available upon request.

TECHNOLOGY INSTRUMENT CORP.

523 MAIN ST., ACTON, MASS. COlonial 3-7711   West Coast Mail Address P.O. Box 3941 North Hollywood, Calif. POplar 5-8620

get PRESSURE INSTRUMENTS *FAST* from F&P



Fischer & Porter now proudly offers a complete line of pressure instruments for one week shipment from stock. These accurate pressure instruments may be used to measure vacuum pressure or gauge pressure from absolute zero to 1,000 psig.

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